Leonard N. Thompson, President, 1945–1946

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The Appropriation of Water for Beneficial Purposes

Report of the Committee appointed by the Governor of Kansas to study and investigate the laws of the state relating to the appropriation of water, submitted Dec. 28, 1944

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Water has been ever regarded as one of the most basic natural resources necessary to man's economic development. Every state in the Union and most foreign countries have laws governing the conservation of water or the regulation of its uses. The states have variously dealt with rights of water use by recognizing, sometimes in modified form, the theory of the common law; by adopting in the beginning the doctrine of appropriation; or by, as many of them have, adopting the common law and later changing to the appropriation doctrine.

Most western states have adopted the appropriative doctrine either exclusively or in part for surface water because it leads to maximum development and use. In some states, such as Nevada, Wyoming, Utah and Colorado, the riparian doctrine was repudiated in favor of the doctrine of appropriation either by law or constitutional provision. Others, such as Nebraska and Oregon, have superimposed the appropriation doctrine on a system recognizing common-law rights in use at the time of the adoption of the appropriation procedure.

In Kansas, the first territorial legislature, in 1855, adopted the common law of England as "the rule of action and decision in this territory." In 1868, the legislature reaffirmed the adoption of the English common law, but expressly subjected it to modifications by constitutional amendments, statutory law, judicial decisions or the conditions and wants of the people. Beginning in 1866, the state legislature, by numerous acts, extending over a period of several decades, sought to authorize the appropriation and diversion of water, and, beginning in 1876 and following, the rule of priority of right. These acts, which are similar to the laws of other states, are cited

and their significance discussed in more detail later in this report.

In the 1917 act, the legislature sought, the Committee thinks, to set up an administrative agency to have control over the appropriation and use of water, such as had already been created, first in the western states and more recently in some of the eastern states.

In a number of western states, the administrative agency is the office of the state engineer. States in which he is the administrative officer are, as a rule, those which adopted the appropriation doctrine from the beginning. Other states set up different agencies. Nebraska created a State Board of Irrigation, which is now the Bureau of Irrigation, Water Power and Drainage. California created a State Water Commission which successively became a Division of Engineering and Irrigation, a Division of Water Rights and now a Division of Water Resources of the Department of Public Works. Oregon has a Division of Hydraulics of the Department of Conservation and Development. Montana is the only western state except Kansas which has not effectively provided by statute for state control over the appropriation and administration of water. In that state notice of intention to appropriate water is still filed in the county in which the diversion is to be made, under a statute similar to the Kansas act of 1886.

In the east, as it became necessary to control the diversion and use of water, notwithstanding the early adoption of the common law, such agencies as the Water Policy Commission of New Jersey, the Water and Power Resources Board of Pennsylvania and the New York Water Power and Control Commission were created. The latter agency, among other things, administers the "police power" act, which imposes very strict control on the development of ground water in certain parts of the state.

It is essential to notice that the Kansas acts have not been effective in superseding the common law and establishing an orderly system for the appropriation and use of water. While the legislature provided that the common law can be modified in accordance with the conditions and wants of the people, the way in which such statutes have come before the court for interpretation has resulted in the reaffirmation of the common law. The latest case was that of *State, ex rel., vs. Kansas State Board of Agriculture* (158 Kan. 603, June 1944) where the court held the 1917 statute ineffectual to establish an administrative procedure for the appropriation of water.

The situation created by this decision left Kansas as the only one of the seventeen western states without any effective statutory procedure for the appropriation of water, and the only one among sixteen of them without administrative procedure for the initiation and perfection of water rights.

Appointment of Committee and Its Procedure

In view of the situation existing in the state as a result of this decision by the court, and as a result of suggestions made to the governor indicating that a committee should be appointed for the purpose of studying and investigating the laws of the state relating to the appropriation of water and reporting its findings and recommendations to him, Governor Andrew F. Schoeppel on Aug. 17, 1944, appointed the following as members of such Committee:

Henry S. Buzick Jr., Sylvan Grove —banker, farmer, stockman and state senator-elect.

Vern R. Mayo, Garden City—farmer, oilman and state representative.

Chris C. Green, Courtland—banker and state representative.

J. G. Somers, Newton—City Attorney and former Judge, Ninth Judicial District.

Paul W. Applegate, Wakeeney—attorney and Kansas Director of National Reclamation Association.

Dr. Frederic H. Guild, Topeka—Director, Research Department, Kansas Legislative Council.

William E. Long, Topeka—Secretary and Director, Kansas Industrial Development Commission.

A. B. Mitchell Lawrence—Attorney General of Kansas.

Gaylord R. Munson, Junction City —President, Kansas State Board of Agriculture and former state representative.

George S. Knapp—Chief Engineer, Division of Water Resources, State Board of Agriculture, *Chairman.*

The Committee held its first meeting at Topeka on Sept. 11, 1944, at which time, after going into the problem in its various aspects, it decided to hold a public hearing, or conference, to which it would invite Kansas water users, persons and agencies interested in the development of water, water experts of other states and of the federal government to discuss the problem. This in order that the members of the Committee might not only be fully advised as to the needs and desires of the people of the state, but also concerning the experiences and laws of other states.

The Committee was particularly interested in the laws of Nebraska, and the operation of such laws, for these reasons: (1) That, as territories, Kansas and Nebraska were created by the same act of Congress—the Kansas-Nebraska Bill of 1854; (2) that, as to legislation relating to water rights, the territorial legislatures of both, in 1855, adopted the common law of England; (3) that, thereafter the state legislatures of both states, extending over a period of several decades, enacted statutes much alike, as will be shown later, the purpose of which was to provide for a system of appropriation of water for beneficial use based on the rule of priority of right.

This conference was held at Topeka on Oct. 16 and 17, 1944. A reporter was employed and a complete transcript of the conference was supplied each member for careful study.

Thereafter, the Committee formulated general conclusions and appointed a subcommittee to make a preliminary draft of a report and later, on Dec. 19, 1944, in a final session, it adopted this report.

Change in Character and Amount of Water Use Since Adoption of the Common Law

A great change has taken place first, in the character of water use and second, in the amounts of water needed and used, since the first territorial legislature, in 1855, adopted the common law of England in the newly created territory of Kansas. A census of the territory, taken in January and February of that year, showed a total of but 8,601 people residing in the area. The first needs of the earlier settlers

were, of course, water for domestic purposes and for livestock. To a limited extent the streams were used for navigation. As immigrants moved into the region, settlements grew up around water power sites. The development of water power for milling, sawing lumber and other manufacturing purposes followed rapidly. At that time no water was being diverted from the streams for irrigation, municipal water supplies, or for industrial purposes. The customs of the people were not antagonistic to the principles of common law as the law of the land. As interpreted in an early decision, *Shamleffer vs. Peerless Mill Co.* (18 Kan. 24, 1877), "Every man through whose land a stream of water runs is entitled to the flow of that stream without diminution or alteration." Under this rule water power development multiplied, and by the date of the above case there were more than 175 water power plants in operation.

Water uses under the common law appear to have reached their greatest point in the seventies, and since that time have gone through a steady decline. For all practical purposes navigation has disappeared entirely from Kansas streams. The importance of water power has also gradually diminished. Water power projects dependent upon undiminished stream flow, once almost essential to every community, have become almost a thing of the past. It is probable that at this time there are less than a dozen such plants in actual use. While such use has declined, new uses, based on the diversion of water from streams or underground reservoirs, have sprung up and have increased until, in some areas, the entire flow of the stream is diverted, or withdrawal from underground supplies has reached or exceeded the safe yield or the average annual recharge of the supply.

The earliest of these new uses which did not conform to the common-law rule was the use of water for irrigation. As settlers moved westward, there began the practice of diverting the water from streams to irrigate the land. The state legislature early recognized this practice and gave it approval in 1866 by authorizing the formation of corporations for the construction and maintenance of canals for the purpose of irrigation. Ten years later, in 1876, the legislature sought to protect the investments made and uses established against depletion of the water supply by subsequent projects—in other words, to establish the rule of priority of right—by an act which provided that "It shall be unlawful for any corporation or person to locate or construct any irrigating canal along or upon any stream of water, or take and use the waters of any stream in such a manner as to interfere with or in any wise hinder, delay or injure any milling or irrigating improvements already constructed or located along or upon any stream of water, or to diminish the supply of water flowing to or through any established irrigating canal." (Ch. 58, L. 1876, 17-618 G. S.) It was under these acts that the five large irrigation canals in Finney and Kearny counties were built, the first of which was started in 1879. So completely have these canals developed the water supply of the Arkansas River that for months at a time no water remains in the stream at Garden City. Furthermore, all of the water thus diverted is carried to nonriparian lands, some as far as 30 mi. from the point of diversion. In other parts of the state smaller projects divert water from streams for

irrigation, either by diversion canals or by pumping.

Recent years have also seen the extensive use of ground water for irrigation. The 1940 U.S. Census reports 1,638 wells being pumped for irrigation in 1939 as compared to 772 wells in 1929. The yield of these wells is reported to be 863,663 gpm., equivalent to 1,240 mgd. Such wells were shown to be in use in 32 counties in the state, with the largest numbers in Finney, Kearny, Ford, Scott, Hodgeman and Pawnee, respectively. No information is available to the Committee as to the increase in use of ground water for irrigation in Kansas since 1939 except in Scott County where the number of pumping plants in operation increased from 64 in 1939 to 118 in 1943. So extensive has the use of ground water for irrigation become in general that in some instances the ground water level is steadily declining while in others large quantities of surface water (stream flow) is going into ground water recharge.

Another use, requiring the diversion of surface or ground water, which has its beginning long after the adoption of the common law, is for municipal water supplies. Information is not available as to dates of the earliest municipal supply systems. There were no incorporated cities prior to 1855, and certainly no municipal water systems. In 1944, 379 cities provide municipal water supplies, diverting the water either from streams or from ground water. As to some of them, use is small, as to others, it is large. One city, drawing on a distant ground water source, has a maximum demand of 32 mgd.

Newest to create a demand on the state's water supplies are large industries. Early, creameries and cheese factories used small quantities of water. Later, meat packing plants, oil refineries and industries of that kind required larger amounts. Recently, newer industries are coming to the state which require in their manufacturing processes much greater amounts. Two may be mentioned particularly: the Sunflower Ordnance Works which has appropriated 60 mgd. of surface water and 10 mgd. of ground water, and the Goodyear Rubber Company, which is constructing a rubber and tire plant and which is developing a ground water supply of 6 mgd. necessary in the processing of the rubber.

In addition to these, there is starting in Kansas the practice of appropriating water from streams for the purpose of repressuring partly exhausted oil fields. This use may in time require large quantities of water, and is one which is wholly consumptive in nature because no water so used can be returned to the stream.

Air-conditioning is another recent use, but of a nonconsumptive nature.

The foregoing summary shows the great change that has taken place in the state, from an economy which required that stream flow be maintained without diminution and which justified the adoption at that time of the common law, to one which more and more has its foundation in the appropriation and diversion of water for beneficial use.

Inter-relationship of Surface and Ground Water

While uses have been described as being from surface water or ground water, to indicate whether water is diverted from stream flow or pumped from wells, it must be pointed out that they do not constitute separate and independent sources of supply, such that

water can be withdrawn from one without affecting the other.

The source of all the surface and ground water supplies in the state is the rain which falls on the land. A portion of the rain runs off directly into the streams, constituting the more fluctuating part of the stream flow. Another portion, entering and percolating downward through the soil, joins the water table and starts moving slowly but continuously toward an outlet into some stream, the flow of which it helps to maintain. Such water constitutes the more regular and stable part of the stream flow.

Under natural conditions a balance becomes established between infiltration to a ground water reservoir and outflow. A water table becomes established and its slope and elevation varies only with seasonal or cyclic fluctuations in precipitation. When water is pumped from such underground reservoirs, adjustments between draft and outflow take place. The water table is lowered first locally in the vicinity of the wells, then levels off and the outflow is ultimately reduced. If water production, or developed uses, reach or equal the average recharge, outflow into the stream may cease and the low water flow of the stream disappear. In Kansas the relationship between stream flow and commonly used ground waters is such that pumping from wells intercepts water which later would reach a stream and thereby reduces stream flow, or causes the normal stream flow to be absorbed for recharge of the ground water reservoir in that reach of the stream where pumping progresses to the point where the water table has been lowered below the river bed.

In Scott County the water table slopes eastward. Water moving under that area would ultimately reach the upper tributaries of the Pawnee and Walnut. While pumping for the expanding acreage irrigated there (21,320 acres in 1943) has materially lowered the water table, the cone of depression created by such pumping has not expanded sufficiently, at this time, to affect either stream. Water coming from the west, however, is drawn into and retained in that area and thus no longer continues its eastern movement. In the eastern part of the cone of depression the slope of the water is reversed. It now flows to the west toward the center of the cone. Because of the slowness with which water moves through the earth, the effect of pumping for irrigation has not yet been felt to the eastward, but ultimately it will, for water which is thus intercepted and consumed on its way to a stream obviously never can reach the stream.

A similar situation is found in northern Grant and Haskell counties where there is also a large and potentially productive ground water area which is now being developed. There the water table slopes eastward and southward toward the Cimarron. Both of these areas are on the high plains and remote from streams, but use in them definitely intercepts water on its way to such streams. Thus it will ultimately affect stream flow.

Affecting stream flow more directly is water pumped from wells in the valleys of streams. In the Pawnee Valley, according to the 1940 U.S. Census, 159 wells, having a combined capacity of 126,173 gpm., are pumped for irrigation. The wells are in the alluvial valley and in such locations pumping intercepts ground water on its way to the stream. Because of the close proximity of these wells to the stream

seldom as much as a mile away, the interception of ground water by pumping has already been reflected in reduced low water flow in the stream. This is shown from an analysis of stream flow records.

The contribution which ground water makes to the flow of a stream, while regular from day to day as compared to surface runoff, varies upward or downward in amount with annual or cyclic fluctuations in rainfall. Figure 1 shows the rainfall trend, the trend in base flow or ground water contribution to the Pawnee, and the trend in the number of wells used for irrigation for the eighteen-year period, 1925 to 1942. Beginning with the three-year period ending in 1930 and continuing through the three-year period ending in 1939, the trend in base flow was, in general, sharply downward, decreasing from more than 200 per cent above the eighteen-year average to less than 40 per cent of that average. During this time, the rainfall trend has been only slightly downward, while the trend in number of wells pumped has been steadily upward. Census data for the basin as a whole are not available prior to 1940. The number of irrigation wells in Pawnee County, reported for earlier periods, however, are regarded as being an index of the extent of development. The number has increased from seven in 1920 to 34 in 1930 and 75 in 1940. Thus, with rainfall varying within only relatively narrow limits, the increasing use of water by pumping is reflected in substantial reductions in the base flow of the stream.

In that portion of the Arkansas River Valley in Kearny and Finney counties, pumping from wells for irrigation began more than 30 years ago and has gradually increased. In 1940 the U.S. Bureau of the Census reported 868 wells being pumped for irrigation in those two counties. Most of these are in the river valley between Lakin on the west and Garden City on the east. In 1939 and 1940, the State Geological Survey, the U.S. Geological Survey and the Division of Water Resources, co-operating, undertook a study in these counties of the ground water resources and their utilization. These studies * show that at that time about 20,000 acre-ft. of ground water was being withdrawn annually for irrigation in the Arkansas Valley in eastern Kearny County and approximately 30,000 acre-ft. in western Finney County, a total of about 50,000 acre-ft. (1 acre-ft. equals 325,851 gal. or 43,560 cu.ft.). The effect of this pumping, as it has increased, has been to intercept the ground water which at an early day was moving from the sides of the valley toward the river with a slope of the water table of 2 to 3 ft. per mile.† At the present time, pumping for irrigation has progressed to the point where the movement of ground water into the channel has been stopped, except during very wet periods; the water table is often lowered below the bed of the river and an annual average of 25,000 acre-ft. of the stream flow passing the state gaging station at Syracuse goes into this ground water reservoir as recharge.

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* Geology and Ground Water Resources of Hamilton and Kearny Counties, Bul. *No. 49*, State Geol. Survey; and Geology and Ground Water Resources of Finney and Gray Counties, Bul. *No. 55*, State Geol. Survey.

† SCHLICTER, CHARLES S., The Underflow in Arkansas Valley in Western Kansas. U.S.G.S. Water Supply Paper No. 153 (1906).

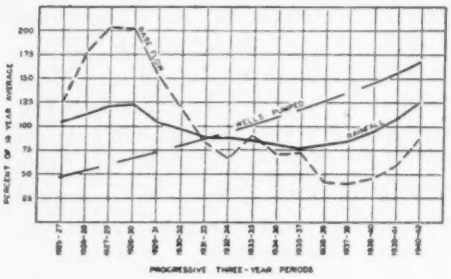

FIG. 1. Trends of Rainfall, Pumping for Irrigation and Base Flow in Pawnee Valley

Lying principally in McPherson and Harvey counties is a ground water reservoir of considerable size and economic importance known as the Equus Beds. These beds, generally speaking, consist of layers of gravel, sand and clay. The source of the water is the rainfall over the area. The Little Arkansas River and its lower tributaries drain this area. Production of ground water in this area has the effect of lowering the water table, thereby intercepting water moving toward the stream, and thus will inevitably decrease stream flow in the Little Arkansas River as it is doing in the Pawnee. With the large amount of water now being withdrawn from the area and increasing demand for water in this area, it is possible also that part of the flow of the stream from above will be absorbed in ground water recharge in the area of production, as in the Arkansas River in Finney County, and that the river channel below often will be left dry.

Sometimes water under natural conditions may be running in a stream at one point, be moving under the land as ground water at another, and later again become stream flow. Such a condition is found in the Cimarron Valley in southwestern Kansas. In the vicinity of Elkhart, the Cimarron is usually a running stream. As the river bends to the north the flow gradually diminishes. At the northernmost part of the bend the channel usually is dry. North of Liberal, or at Arkalon, it is again a running stream, increasing in volume as it approaches the Oklahoma line south of Plains. Figure 2, a map of southwest Kansas, shows this reach of the Cimarron. Numerous measurements have been made by the Division of Water Resources in this reach, of which the following is typical of the low water flow. At the bridge north of Elkhart the flow was 36.5 cfs. North of Hugoton it had diminished to 12.2 cfs. A few miles below it had disappeared entirely and the channel was dry until a point a few miles above the bridge north of Liberal was reached. North of Liberal the discharge was 3.46 cfs., at Arkalon 24.9 cfs. and south of Plains 58.8 cfs. Not until the discharge north of Elkhart reaches more than 40 cfs. does the Cimarron at the Santanta Bridge become a running stream.

In the Cimarron Valley the slope of the water table is from west to east and the water moves eastward under the land across the bend of the river. In this area, the diversion of river water above Elkhart would decrease the amount of ground water moving under Stevens County and ultimately would reduce the water supply below in the stream. Pumping from wells in Stevens County would also reduce stream flow below.

The Committee, in discussing the inter-relationship of surface and ground water in Kansas to the extent it has, does not wish to imply that it believes the development of the ground water resources of the state is unwise from the standpoint of public policy. The beds of sand and gravel found under

FIG. 2. Cimarron River in Southwest Kansas

the high plains in the western part of the state and in certain river valleys constitute valuable natural reservoirs for the collection and storage of water. They provide efficient and economical storage which should be developed to the limit of their safe annual yields. The Committee feels compelled, however, to point out that the source of both water in streams and in such underground reservoirs is the same; that water used from one is not available for use from the other; that the state cannot wisely have a system of water rights for surface water and none for ground water or one system for surface water and another for ground water if there is to be orderly development of the water resources of the state. If those who invest the funds necessary to put water to beneficial use are to be protected in the continued right to the use of the quantity they have developed, against injury through diminution of the supply by later would-be users, a workable code applicable to this interrelated water supply is needed.

Scope of a State's Power Over Natural Resources

A fundamental principle relating to the development and use of certain natural resources is stated concisely and effectively in volume 50, Corpus Juris, page 740, in these words:

> Some things, from their nature, such as light, air, water, mineral oil, mineral gas, and wild animals, must necessarily remain common, subject only to a usufructuary right or to be considered as property only when and while reduced to, and retained in, possession.

That the principles set forth above are fundamental and that the state, under its general power, undoubtedly has authority and it is its duty to control and conserve natural resources for the benefit of its inhabitants, is evidenced by the fact that everywhere statutes have been enacted respecting the right to divert and use water, to produce oil and gas, to take wild game and to navigate the air.

Similar statutes, however, have never been enacted to control the tak-

ing of products such as coal, salt, gravel or other minerals which are fixed in the earth. There is no public community of interest in such property. As to products which migrate either through or over the earth, the taking by one affects another. As to products which are fixed, one owner may remove the same from his property without affecting another owner.

While both of these natural resources, water and petroleum products, migrate under certain circumstances, there are distinct and important differences between laws enacted for the regulation of water use and those for the control of the production of oil and gas. The reasons for the differences in these laws are fundamental. The basic differences between oil and water are with respect to their occurrence in a natural state. Oil and gas were formed in the earth during a geological age long past. The period in which oil was made and collected in the subterranean pools from which it is produced is closed. In its undisturbed condition before the pool is tapped by wells it is not migrating. As the oil is produced, the supply remaining is diminished and is not being replenished. When the oil has all been extracted from a pool it is abandoned. Consequently, investments made and works constructed for the production of oil and gas are made with certain knowledge that when the pool is exhausted the works must be abandoned and the unsalvaged portion of the investment written off as a part of the cost of the production of the oil.

In contrast, water is constantly being replenished by rainfall. Once the rain has fallen, the water does not collect in pools and remain there until used. It immediately starts on its way back to the sea from whence it came. It is under one piece of land today and under another tomorrow; in the stream at one place today and at another tomorrow. If it is unused, it flows on and becomes a wasted resource. Since water is continuously being replenished, investments made and works constructed are based upon the availability of such water for continued use. A city or an industry developing a water supply at great expense does not expect to "pump out that pool" within a given time and go to another, or to exhaust the supply and abandon the city or industry. The water supply is regarded as a continuing thing as long as it is needed. The same is true as to the use of water for irrigation in aid of agriculture and any other beneficial uses.

When an oil pool is discovered, all who are in a position to share in the oil begin production. Failure of one of the common owners to do so results in the loss to him of his equitable share. Laws, and rules based on such laws, therefore provide for off-set wells on adjoining property and for the equitable distribution of the allowable production among all owners.

Water is not so developed. The source of the water supply is not newly discovered. Persons, cities and corporations have initiated their uses, one after another, as they have had need, by diverting water from streams or underground sources. While water supplies are constantly being replenished by the rainfall, such supplies are not unlimited. Development beyond nature's capacity to replenish leads to shortage and to want. Where a number of developments are made from the same source, the supply which was fully adequate for the early user or users might be seriously interferred with and diminished by later users

It is a wise and sound principle of law that those who first put water to use should not have the supply injuriously diminished and their investments impaired by such later users.

Were the same legal principles applied to the development of water that suitably are applied to oil and gas, as one appropriator after another initiated his use and the water supply became insufficient for all, earlier users would be injured by the diminution of their supply if the available water were to be apportioned among all who sought to use it. The more who seek to use, the smaller becomes the amount which earlier users can obtain. As the available amount is thus divided and redivided, earlier works must operate with ever diminishing quantities below the economic capacities of works, and projects gradually lose their value. Under the more commonly applied rule of priority and right, those who first developed and used the water would not suffer injury, but the later user would be limited to the amount available under the date of his priority.

The Two Doctrines of Water Law

The law of water rights embraces the common-law doctrine and the doctrine of prior appropriation. The common-law doctrine of riparian rights is based upon the ownership of land contiguous to a stream without regard to the time of use or to any actual use at all. Under the strict common-law doctrine the owner of riparian land is entitled to have the stream flow by or through his land undiminished in quantity except for domestic and livestock uses, and unchanged in quality. The right to use for irrigation or other uses under the common law is a modification of the common-law doctrine made by the court. It is a right to the use of the flow of the stream, with due regard to the equal right of all other such owners to use it for a similar purpose, and not ownership of the water itself.

Under the common-law doctrine the right to use stream water is regarded as real property and entitled to protection to same extent as other property. After the water has been diverted from the natural source and reduced to possession, the water itself becomes personal property of the common-law claimant.

The common-law right to the use of water arises by operation of law as an incident to the ownership of land, of which the right is an appurtenance. Only land contiguous or abutting upon a natural stream or lake is riparian land.

The common-law doctrine is not founded upon use, and in absence of statutory modification, this right is not lost by nonuse.

The right to the use of water from water courses by contiguous landowners results solely by reason of location, and regardless of relative productive capacities of such lands or uses. The right attaches to the land at the time such land passes to private ownership. It is co-equal with the right of every other riparian owner on the stream regardless of the relative dates on which the several tracts passed into private ownership.

The common-law rule which applies to ground water is not designated as riparian. It is the right of ownership of the water while it is capable of being captured on the land of the title holder.

The English or common-law rule relating to ground waters is well set out in 55 A. L. R., page 1390, as follows:

> Under the general doctrine as to rights in percolating waters, known as the common-law or English rule, they are regarded as

belonging to the owner of the freehold, like the rocks, soil and minerals found there, and such owner may, in the absence of malice, intercept, impede, and appropriate such waters while they are upon his premises, and make whatever use of them he pleases, regardless of the fact that his use cuts off the flow of such waters to adjoining land and deprives the adjoining landowner of their use.

The statutory doctrine of prior appropriation is based upon the time of use and the actual application to beneficial use without regard to the ownership of land contiguous to the stream or of overlying land. This right attaches to the water course or ground water source of supply and is a right to the use of the water from such source, not ownership in the water itself.

This doctrine lays emphasis upon beneficial use and affords protection to investments in enterprises for diversion and use of water for such purposes.

The quantity of water appropriated depends upon the amount claimed and which has actually been applied to beneficial use. Some water codes place a limit on this quantity and others leave it to be fixed by the state administrative official.

Beneficial use may be for various purposes, such as domestic, irrigation, municipal, industrial and power.

The place of use, as distinguished from point of diversion, is another basic element of the appropriation right.

The essence of the appropriation rule is the right of an early appropriator to continue to divert from a source when the supply naturally available becomes insufficient for all those holding rights, the first in time being the first in right as determined by effective date of the appropriation. As the volume of a stream drops, the diversion gates of appropriators are closed in reverse order of their priorities, and as it increases the gates are opened in the order of priority. The same principle applies as to ground water sources as rate of recharge decreases and increases, fluctuations in the water table being indicative of the change in supply.

The priority of appropriation dates from the time of the taking of the initial step required by the statute—usually the filing of an application with the state administrative official—provided reasonable diligence is pursued in completing the diversion works and actually applying the water to beneficial use.

Since water rights—rights to use water—are a form of property, jurisdiction to determine these rights is necessarily vested in the courts in the last analysis.

As a general rule an appropriative right is an appurtenance to the land, but not necessarily so. In most states it can be conveyed apart from the land on which it is used by the holder of the right, provided the rights of others are not prejudiced. Its conveyance is presumed to pass with a conveyance of the land, along with other appurtenances, except where there is a specific reservation.

Appropriative rights are commonly subject to loss through:

1. Voluntary abandonment
2. Statutory forfeiture
3. Adverse use by another
4. Estoppel

What we know as the common law, as applied to water, had its beginning in England. English colonists settling on the east coast brought the laws of England to the United States and the common law became the basic law of the eastern states.

Early Spanish emigrants settled in Mexico and, moving northward, brought to this country the law of southwestern Europe. This law had its origin in Imperial Rome. When the Pilgrims landed at Plymouth Rock in 1620 such towns as Taos and Santa Fe, west of the Mississippi River, were the political and commercial centers of this western area. The customs and laws of this western area concerning water and water rights had as their background the old Roman water law, and such influence existed when these western states were created.

Roman civil law is historically distinct from English common law. The Roman civil law concerning water and water rights and the doctrine of prior appropriation as interpreted and applied in many American states are remarkably alike.

The Roman law ordained that:

> . . . ancient water rights, established by long ownership, shall continue to the individual citizens, undisturbed by innovation: [and if a flow of water through certain places] is according to custom and shows usefulness in irrigating certain tracts of land, no innovation against the old form and established custom will be permitted; [and] it is not acreage, but the use to which water is put, that measures the right to the water.

The Roman civil law further ordained that water for domestic use had the prior right; that water for livestock and private gardens was next; that water for fields came third; that water for mining and mechanical purposes came last.

The Change From the Common Law

The common-law doctrine as applied to water use was not adopted in this country because legislative bodies at the time of its adoption gave considered thought to the wants and needs of the people. The early settlers coming from England, as they did, to the eastern part of the United States, and being in need of the blanket adoption of general laws, chose the English common law. No special constitutional or statutory enactments having been adopted to deal with water use questions, this blanket or supplemental law was construed as controlling when disputes later arose.

Some states through their legislatures or their courts have later modified the common-law doctrine of water use and water rights; others have rejected it entirely on grounds that it is wholly unsuited to the physical conditions in their states.

The basic principle of the common-law doctrine as applied to streams, namely, that each person owning land bordering upon a stream shall have the right to have such water continue to flow past his land undiminished by any use, other than domestic and stock watering, has been modified by legislatures in some states to permit the diversion and use of water from such streams for beneficial purposes, such as irrigation. The courts in some states have modified the common law to hold that the use of water for irrigation was one of the common-law rights of the riparian owner, but that such use must be made with due regard to the equal right of every other riparian proprietor to use water from the stream for a similar purpose.

The early uses were of a character which would not diminish the flow or water supply in the streams. They were largely navigation and water power uses. Uses which could be administered, more appropriately, under the appropriation doctrine developed after many, and probably after most, of the states had been admitted to

statehood. Where the legislatures found the common-law doctrine unsuited to the physical conditions or the character of water uses then being developed in their states, they rejected such doctrine and provided for the more workable doctrine of prior appropriation.

The doctrine of prior appropriation was not new to the peoples of the western territory who had been subjected to government under Roman civil law. This western land was the territory carved into the states which were the latest to be admitted to statehood. Early settlers of this land were miners and the irrigation users. These people were the first to feel the need to divert and use water and to be protected in the continuous use of a water supply. The conflict of municipal and industrial uses with the common law in other regions was not equally demanding the attention of the legislatures or the courts of the older states at that time—the eastern states.

The doctrine of prior appropriation, in the form in which it has developed in the United States, was first recognized by courts as applied to the gold miners of California. It was later extended to agricultural irrigation uses and for other purposes. Later, water codes were enacted which provided for the posting and filing of notices, and for the beginning of the construction of works within a specified time. Statutes of this kind, known as water-use posting laws, have been generally succeeded by more complete water codes throughout the western states. These water codes are founded upon the basic principle that priority of use determines priority of right to continue such use. Such codes are quite uniform in providing for appropriations by applications to a central state agency, which is charged with the conservation and distribution of water in the public interest. This doctrine has been crystallized into the term "First in time, first in right."

Many of the states which came into statehood with their constitutions silent on water use rights, and with early legislatures recognizing the application of the common-law doctrines on this subject, have now abandoned this doctrine as impractical and ineffectual in promoting development and conserving this natural resource. Other states have by constitutional amendments, legislative enactments and judicial decrees modified the common-law doctrine by subordinating it to the doctrine of prior appropriation; they have provided for the protection of common-law rights then in use, against impairment, by administrative or judicial determination of such active uses; and have either terminated unused common-law rights under police power or have provided for a system of compensation of these undeveloped potential rights.

Among these states, the Committee calls attention more particularly to: California, which for many years, almost from the beginning, attempted to work under the co-existence of both the common-law and appropriation doctrines with great confusion and resulting litigation, and more recently by both constitutional amendment and a change of judicial view, has veered strongly to the rule of prior appropriation; Oregon, which in the beginning recognized the common law exclusively, later changed to the appropriation doctrine under a procedure which gave security to actual uses established under the common law, but which terminated common-law rights unused; New Jersey and New York

common-law states, whereby through the exercise of the police power close administrative control has been provided over the appropriation and diversion of both surface and ground water to attain much the same results as are secured by the appropriation doctrine; and Nebraska, which started as a common-law state, but early recognized the deficiencies of that theory of water rights, and changed to the rule of appropriation when it became increasingly apparent that the common-law doctrine had less to offer for the conservation and utilization of the waters of that state.

California

Both doctrines have existed in California. In 1928, by constitutional amendment it was declared: "that because of the conditions prevailing in this state the general welfare requires that the water resources of the state be put to beneficial use to the fullest extent of which they are capable, and that the waste or unreasonable use or unreasonable method of use of water be prevented, and that the conservation of such waters is to be exercised with a view to the reasonable and beneficial use thereof in the interest of the people and for the public welfare."

Riparian and other rights in water courses were limited to the portion of flow for reasonable and beneficial purposes under reasonable methods of diversion. After the rights of a common-law owner to a reasonable beneficial use have been satisfied, he has no further right to require that excess waters be permitted to flow past his lands unused. He cannot enjoin a subordinate appropriator from using water in a way not injurious to his right. The common-law user does not have the right to store water for future needs, although he may temporarily detain it in reservoirs for particular and immediate needs. Seasonal storage, therefore, is not a proper riparian use but constitutes an appropriation of the water.

The water code provides that running water flowing in a stream is subject to appropriation (1872); that all waters are the property of the people of the state (1911); that permits may be issued for any unappropriated water, or water which, having been appropriated or used, flows back into a stream, lake or other body of water (1913).

The statutory procedure for appropriation is initiated by application to the state engineer, who is chief of the Division of Water Resources. This is the exclusive procedure for obtaining appropriation rights. The Division of Water Resources is authorized, upon receipt of petition therefor, to make determinations of rights to use water acquired under the act as well as common-law rights; the order and record of determinations are filed in court as the basis of an adjudication. The lower courts may, in their discretion, refer to the Division of Water Resources, as referee, suits brought before them for the adjudication of water rights, subject, of course, to their review. The division may act as master or referee when requested by the court. The supreme court has reminded trial courts of their power to call upon the state organization for competent expert assistance on complicated technical problems in water right cases.

The state engineer is given statutory authority to divide the state into water districts, conforming to watersheds or otherwise, and to appoint commissioners, watermasters or deputies to supervise and effect a proper distribution of

waters. This is also true in Oregon and in Nebraska.

Oregon

The early court decisions followed the common-law doctrine. The courts have, however, consistently held that the rights of an appropriator are superior to common-law rights where the latter claims were not based upon actual beneficial use. The common-law doctrine has been largely abrogated by statute and court decision in favor of the appropriation doctrine except as to vested rights of use which are principally for domestic and stock watering purposes.

The courts have held that a person cannot claim rights both as a riparian proprietor and as an appropriator, and having asserted the one, he waives the other. A claim of right to use a fixed quantity of water to exclusion of others is an appropriator's claim.

The water code of 1909 provided that "All water within the state from all sources of water supply belongs to the public" and that "Subject to existing rights, all waters within the state may be appropriated to beneficial use, as herein provided, and not otherwise; . . ." Multnomah Creek and a part of the Columbia River are excepted. This code limited common-law rights to the extent of the actual application of water to beneficial use made prior to the passage of the act, or within a reasonable time thereafter by means of diversion works then under construction (47–401, 47–402 and 47–403, Ore. Code An. 1930; *In Re Hood River,* 114 Ore. 112; *Calif.-Ore. Power Co. vs. Beaver Portland Cement Co.,* 73 Fed. 2d 555).

The effect of the common-law doctrine in Oregon under present statutes and judicial decrees is little more than legal fiction. The appropriative procedure includes an application to the state engineer, permits to appropriate water, certificates of appropriations, determination of water rights by the state engineer, followed by judicial decrees, and distribution under supervision of the state engineer.

Upon receipt of petition for adjudication of water rights the state engineer makes findings of fact and definitions of rights which he files with the court; the court then proceeds with a hearing in the nature of an equity proceeding and enters an order affirming or modifying the determination of the state engineer.

New Jersey

The constitutions of New Jersey, as adopted in 1776 and revised in 1844, both contained specific provision that the common law of England should control in that state as basic law, and were silent as to water uses and water rights.

In New Jersey there has been a partial control of water development since 1907. Control is through laws which provide that no water district, person or corporation supplying water to the inhabitants of any municipal corporation shall have power to condemn water or water rights or to divert water, surface or subsurface, without the approval of the State Water Policy Commission. Favorable action apparently does not establish a grant of any right to use the water, but is a permit to divert from that source (Ch. 252, L. 1907, and Ch. 304, L. 1910).

The city of East Orange (1931) was required to pay damages to an overlying landowner where the water beds were diminished, in spite of the fact that the application of the city to

divert ground waters had been approved by the State Water Policy Commission (*Braidbun Realty Corp. vs. East Orange,* 107 N. J. L. 291; 153 Atl. 714). The commission has refused to approve an application for some requested developments for public supply and has thus controlled, in effect, the use of water.

In 1908, Justice Oliver Wendell Holmes said in the case of *Hudson County Water Co. vs. McCarter, Attorney General of State of New Jersey,* 209 U.S. 349:

> . . . Few public interests are more obvious, indisputable and independent of particular theory than the interest of the public of a state to maintain the rivers that are within it substantially undiminished, except by such draft upon them as the guardian of the public welfare may permit for the purpose of turning them to a more perfect use. This public interest is omnipresent wherever there is a state and grows more pressing as population grows. It is fundamental and we are of the opinion that the private property of riparian owners cannot be supposed to have deeper roots.

And in 1923 in case of *Trenton vs. New Jersey,* 262 U.S. 182, it was stated:

> The state undoubtedly has power, and it is its duty to control and conserve the use of its water resources for the benefit of all of its inhabitants.

New York

New York has a similar but later law. A 1933 amendment to the New York law prohibited the subsequent installation or operation of any new or additional wells on Long Island for purpose of taking ground water for manufacturing or industrial purposes, where the capacity of such wells, singly or in the aggregate, is in excess of 100,000 gpd., without first obtaining the approval of the State Water Power and Control Commission.

This act refers to investigations "which indicate that the depletion of underground water under Long Island is such as to threaten the adequacy of water supply for domestic consumption of the inhabitants thereof" and further states that "this enactment is made in the exercise of the police power of the state and its purposes generally are to protect the public health and public welfare in conserving the supply of water for domestic consumption."

More than 300 applications for approval of such wells were filed during the first five years following passage of this act, of which 204 were to be used for air-conditioning. A limitation imposed in the granting of approval for such applications was that the water be returned to the ground through "diffusion wells." About 7 mgd. was involved in such applications for air-conditioning uses and several million gallons a day more for about 40 industrial wells. The restrictions put on the use of water by the commission under the operation of this statute has undoubtedly helped to retard the occurrence of serious results, such as the intrusion of salt water.

Nebraska

The Nebraska constitution, when that state was admitted to the Union, did not include the common law of England in its provisions. This was provided by legislative enactments. The common law as applied in this state was its only constitutional or legislative law which was applicable to water uses and disputes.

In 1889 the Nebraska legislature enacted a water-use notice posting statute, which was amended and supplemented to become the 1895 water appropriation act. The fundamental features

of this appropriation water code were included, without any substantial change, in Nebraska's new constitution of 1920.

The Nebraska water code, and later also the constitution, dedicated waters of the streams to the use of its people; they provided for a census and determination of actual water uses then in existence in each watershed.

The effect of these statutes, and court decisions construing them, was discussed with the Committee by Mr. John L. Riddell, Assistant Attorney General of Nebraska. Mr. Riddell's statement to the Committee is summarized as follows:

The common-law owners who had not initiated any actual use of water were limited to an action at law against appropriators subsequently developing water uses under a permit from the state administrative agency for earlier appropriation uses perfected under the water code. Appropriation users were granted injunctive relief against later common-law claimants of right to use stream water, although the common-law claimant can, of course, make application as a would-be appropriator.

Nebraska court decisions in 1895 and 1903 construing the appropriation water code held that the common-law doctrine still existed in that state in co-existence with the appropriation doctrine (*Clark vs. Cambridge and Arapahoe Irr. & Imp. Co.*, 45 Neb. 798; *Crawford Co. vs. Hathaway*, 67 Neb. 325, and *Meng vs. Coffee*, 67 Neb. 500). The apparent result of these decisions was that common-law rights attached to lands which were patented prior to the effective date of the 1889 legislation, but that the appropriation doctrine applied to lands subsequently patented. The common-law doctrine was modified to permit a reasonable amount of water for use for irrigation purposes on riparian land.

In the later decisions of 1904 and 1905 (*Cline vs. Stock*, 71 Neb. 70; and *McCook Irrigation and Water Power Co. vs. Crews*, 70 Neb. 103) the relation of the existence of these two doctrines was further considered. In the McCook case a downstream appropriator began use of water earlier than an upstream common-law claimant. The appropriator sought to enjoin the common-law user from his subsequently initiated use to the injury of the appropriator. The Nebraska supreme court first held that the appropriator must first do equity by tendering damages to the common-law owner, but upon a rehearing the court held that such damages need not be tendered, and that the only remedy of the upstream common-law claimant was a suit at law for damages if any such damages could be proved.

In the Cline case, a downstream common-law claimant sought an injunction against an upstream appropriator. Here again the supreme court first favored the common-law claimant, but upon a rehearing held that the common-law owner was not entitled to injunctive relief, and that his sole remedy was an action at law for such damages as he could prove.

Since the common-law claimant with his so-called superior right, under a patent antedating the appropriation code, is denied any equitable remedy as against an earlier appropriator, the practical effect is that the appropriator's right under his permit from a state agency which seeks to conserve the natural water resource is superior to the common-law claimant's right.

The court had previously held in the Crawford case that the riparian owner

does not own the water, but only a right to enjoy the advantage of a reasonable use as it flows by his land.

While Nebraska has recognized the co-existence of both doctrines, the procedural aspects of the appropriation doctrine may be summarized as an exercise of eminent domain as to riparian owners.

The grant of an appropriation permit does not injure the riparian owner. He has no priority or preference either up or down the stream. His right to a reasonable use must take into consideration the reasonable requirements of all other riparian lands. He cannot prove or recover damages for the water taken by appropriation when his interest or share in the allotment taken under this appropriation condemnation statute is so infinitesimal as to become valueless. On this point Mr. Riddell said:

> Our experience is, whenever you develop a [irrigation] project, the riparian owner usually has more water flowing by his place, a more steady, constant flow of water throughout the year, than ever before. We find from the examination of the records, that our Platte River was dry clear up into Colorado in the year 1855, before we took a drop out for irrigation. And now since projects have been built on it and the Kingsley project has been finished the Platte River wasn't dry this year down as far as Grand Island. It is true we had more rainfall this year than usual, but we are irrigating by return flows thousands of acres that prior to the development of these projects didn't have any water at all except in the spring or fall. There is nearly a million acre-feet annually of return flows developed from irrigation projects in the western part of Nebraska, the Scottsbluff country, that flow back into the stream. We catch that in the Kingsley reservoir and use the water again. Our experience is that the riparian owner is better off when projects are developed, and if he is better off he cannot be damaged, and if he is not damaged he cannot collect any damages.

Comparison of Legislation and Judicial Decisions in Kansas and Nebraska

1. *The marked similarity between legislation in Kansas and Nebraska.* First of these was the adoption of the common law of England by the territorial legislatures, both in 1855. Next, Kansas in 1866 and Nebraska in 1877 authorized the formation of corporations for the purpose of constructing and operating irrigation canals. Both states, Kansas in 1886 and Nebraska in 1911, authorized a change in the point of diversion if others were not injured thereby. In 1886, the Kansas legislature passed a more comprehensive act, setting up statutory procedure for the appropriation of water. This is known as the notice posting act. Nebraska passed an almost identical act three years later, in 1889. In 1895 Nebraska created a State Board of Irrigation and gave it an administrative control over the appropriation of water. Kansas created a State Board of Irrigation the same year, but gave it no administrative functions. In 1917, however, it set up a Water Commission, intending, the Committee believes, to give it somewhat similar administrative functions, since the two acts are much alike in their fundamental provisions, as is shown later under the head of "Administrative Procedure."

2. *The trend of judicial decisions.* In the beginning the courts of both states recognized the rule that the riparian owner was entitled to the flow of the stream without diminution. Later, in both states, the right to the use of water for irrigation was recognized as one of the common-law rights of the riparian owner. Thereafter the courts of Nebraska veered so strongly

to the doctrine of appropriation that this doctrine is now in force in that state with its full vigor. The Kansas court, in its latest irrigation case (1936), reaffirmed its former decisions.

3. *The nature of cases.* It should be pointed out that in the two principal irrigation cases in Kansas, *Clark vs. Allaman* and *Frizell vs. Bindley*, the issues drawn were between individuals only, both of which in each case were diverting to riparian lands only. No cases parallel with those of *McCook Irrigation and Water Power Co. vs. Crews*, or *Crawford Co. vs. Hathaway*, where diversions were being made to nonriparian land, have been before the Kansas court. The five large irrigation canals in Finney and Kearny counties were constructed in the 1880's, the first started in 1879. Irrigating around 65,000 acres, at the present time, they divert water to nonriparian land entirely, some as much as 30 mi. from the point of diversion. Although they divert the entire flow of the Arkansas River except in time of flood, no riparian owner below has, since their construction, challenged their right to divert.

Administrative Procedure

In all but one of the seventeen western states, and in a number of those in the east, the legislatures have set up an administrative procedure for the appropriation and use of water under a suitable state agency. Commenting on the advantage of this procedure over the earlier procedure of posting or recording a notice of intention to appropriate, Mr. Wells A. Hutchins, Senior Irrigation Economist, U.S. Department of Agriculture, who appeared before this Committee in response to its invitation, in his work, "Selected Problems in the Law of Water Rights in the West," states: *

> The advantage to the public of a centralized system for the acquisition, determination and administration of water rights, consistently applied, lies in the higher degree of order and definiteness of rights which it affords. Priorities to water of a long stream system become a matter of record in one office, instead of being based upon filings in a number of counties and upon acts of applying water that may not become matters of record. Determinations of rights are made in comprehensive proceedings, based upon public records and surveys, in which the state engineer participates, rather than in a multiplicity of suits between individuals. And distribution of water according to priorities on the stream system is co-ordinated under one public authority.
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> . . . . . .
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> However, while the system as a whole has not been applied as completely in some jurisdictions as in others, and has not met with uniform success in all places, it is undeniable that a long period of time has shown that centralized control over water right functions is workable. The system is generally conceded in the West to have been of marked public benefit. None of the states which have imposed public control have receded from the principle, excepting in those instances in which specific functions have been rendered inoperative as the result of unfavorable court decisions. The general principle is now well established in most of the western states, for it is widely realized that the foundation of the system is the vital interest of the state in its water resources.

A. E. Chandler, another authority on western water law, has commented thus on legislation of this kind: †

> It must be emphasized that the new legislation controlling appropriations is based upon no new legal principles. It simply

* HUTCHINS, WELLS A. Selected Problems in the Law of Water Rights in the West. Misc. Pub. *No. 418*, U.S. Dept. of Agric., pp. 77–78.

† CHANDLER, A. E. *Elements of Western Water Law*, p. 156.

offers an improvement in the details of administration—just as a modern auditing system makes it possible for a business house to control more easily its operations. Under the new system the appropriator is under state control from the initiation to the completion of this project. It is a control, however, which protects, rather than prohibits, bona fide projects. Under the old method of posting notices, the records were useless as evidences of work actually done, and one was never certain of the status of his right during construction.

The administrative procedure in many of the western states is, in general, similar to that in Nebraska under the act of 1895. This procedure was discussed with the Committee by Dan S. Jones, Assistant Chief of the Bureau of Irrigation, Water Power and Drainage, one of the administrative officials of that state, and is briefly summarized as follows:

The State Board of Irrigation was directed by statute to determine the priorities of all appropriators of the public water of the state. That was done by river basins. Notice was given by publication and otherwise so that all interested parties to the proceedings were given a hearing. The board took notice of the time of first use, the amount of land that had been irrigated, or, if it was for other use, they took all pertinent evidence as to that, and made a determination of such old rights. Anyone aggrieved by the determination of the Board might appeal to the district court.

The board was also directed to see that all laws relative to the distribution of water were administered in accordance with the rights of priority of appropriation.

Thereafter persons or corporations intending to appropriate water have been required to make application to the board for a permit to appropriate. If there is unappropriated water in the source of supply named in the application, and if such application and appropriation when perfected is not otherwise detrimental to the public welfare, the application is to be approved. As to details of administration, when an application is received by the department it is given a priority date as of the date of filing. Within 30 days the department makes an examination of the application and if corrections are necessary it is returned to the applicant within that time. Upon receipt of the corrected application, if there is unappropriated water, the application is approved by a proper certification of the state engineer. In this approval no allotment of water for irrigation is to be made of more than 1 cfs. for each 70 acres of land, nor 3 acre-ft. in the aggregate during one calendar year. These are upper limits. The department now allows that amount in the western part only and adjusts the amount on a sliding scale to 1 cfs. to 140 acres as far east as Grand Island, the theory being that as the rainfall increases going to the east, the irrigation requirements become less.

When the application is approved, provision is made that the works must be constructed within a reasonable time. A provision is made for an extension of time if good reason is shown for such extension. When the state engineer is satisfied that the works have been completed and that water has been applied to the land in accordance with the provisions of the permit he then shall issue a certificate of appropriation appurtenant to the land to which such water has been applied.

The Kansas Water Commission Act of 1917, while indefinite in some respects, and the Nebraska Act of 1895 had these fundamental provisions in common:

1. Both provided that the waters of the state might be appropriated by application to a designated state agency.
2. Priority of right (prior application) was to govern in making allotments.
3. Appropriations in excess of the reasonable needs of the appropriators were not to be allowed.
4. Waters appropriated for irrigation were to become appurtenant to the lands to which they were applied.
5. Water appropriated should remain subject to the principle of beneficial use; that is, the right would be lost by nonuse.

Immediately upon the repeal of the notice posting statute of 1886 (42–101 to 42–105, G.S. 1935) by the 1941 legislature, applications began to be filed with the Division of Water Resources under the provisions of the 1917 act for permits to appropriate water, the first being on May 6, 1941. Because of the similarity of the Nebraska and Kansas acts on these five points, the department, in setting up administrative procedure to process such applications, carefully studied and closely followed the operative procedure in practice in Nebraska.

Since Nebraska, in setting up an administrative system for the appropriation of water, at the time the notice posting procedure in that state was abandoned, found it desirable to make a determination of all uses (priorities of appropriations) in effect when the change from one system to the other was made, and since the 1917 act (24–902) apparently authorized the department to make such surveys and investigations as might be necessary to a complete knowledge of the subjects assigned to it for investigation, the Division of Water Resources made a survey of water used in each river basin, as applications began to come from such basins before starting to process such applications. The purpose of these surveys was not to determine the rights of any user, but rather the existence of such uses. The determination of questions as to the rights and priorities of any persons in matters relating to the appropriation of water was given, by the legislature in 1891, to the state's courts by Section 42–3,109 of the statutes. The advantage of having public records of this kind based on such surveys, when some water user might bring an action to adjudicate his rights with respect to those of others in the basin, obviously made such surveys desirable.

Upon the completion of a survey and report, a public hearing was held in each area to which all water users listed in the report, as well as applicants, were invited. The purpose of the hearing was to provide a means of correcting any errors in these records as to earlier uses, as well as to acquaint all with such existing uses and the prospective additional uses, and to hear any objections to the approval of applications.

Adjusting the Law to Present Needs

The Committee believes that conditions and the needs of the people in Kansas have changed so greatly since the early adoption of the common law as applied to water use, that the time has come to modify the common law to the extent necessary to set up a system of appropriation, based on priority of right, but without depriving the common-law owner of relief by proper compensation for limitations placed on unused common-law rights.

It believes that unused water cannot wisely be held in perpetuity for a common-law owner who may never

have use for it, without resulting in underdevelopment permitting the water to flow out of the state and on toward the ocean, as an economic waste and loss of a valuable natural resource.

It believes two things are needed: (1) to establish the right of appropriation under the rule of priority of right; and (2) to establish adequate administrative control over the appropriation of water to prevent overdevelopment of any source of supply with resulting injury to established uses.

In order to establish effectually the rule of appropriation, the Committee firmly believes that he who appropriates and puts water to beneficial use should not thereafter be subject to injunction by common-law claimants who have not previously established uses for reduction in the flow of a stream or in the reduction of the ground water source of supply, and that anyone damaged by the appropriator's use should have the right to recover for actual damages.

It is the belief of the Committee that the adoption of the appropriation doctrine does not take from the common-law owner any substantial rights which have value sufficient to be capable of being measured, but rather provides for a system of protection of developments and financial investments in the appropriation and diversion works of the diligent person who perfects his use and realizes beneficial returns, as against such potentially present and almost valueless undeveloped equal rights to divert and use, recognized by the common-law doctrine.

As overdevelopment takes place, each user under the common-law doctrine obtains a smaller and smaller share of the common water supply even if he was among the first to develop his use of water. Furthermore, he sustains a loss of at least a part of his investment as he becomes limited to smaller quantities of water than those for which he built his works. Under the appropriation doctrine, the owner of land abutting on the stream when he begins his use is given the protection which any appropriator receives, in his order of priority, and thus is not subject to injury by later users.

As modified to include irrigation as a common-law use, the common-law owner, who may seek to maintain the sanctity of his undeveloped potential common-law water right to share equally with all others similarly located in the division of the water supply, will in time find himself without a valuable or usable supply. Under the common law he will have a share of the water ultimately too small to be of economic value to himself, as will likewise all other common-law users, including the first who initiated such use.

The protective features of the appropriation doctrine apply alike to both surface and ground water.

Legislation such as it proposed, the Committee believed, was a recognition of customs now in effect, almost by common consent, in southwestern Kansas. Here, since the late eighties, irrigation canals have been continuously diverting the flow of the Arkansas River to nonriparian lands, without any riparian owner, along the stream between there and the Oklahoma line, ever having sought to enjoin such diversions. Hundreds of landowners in the Arkansas and Pawnee valleys who are pumping from wells also are, by such pumping, reducing the flow of these streams. Under the common-law rule as set forth in *Emporia vs. Soden*, all of such pumping could be

enjoined, since, as has been shown earlier in this report, it definitely reduces stream flow. No injunction proceedings have ever been brought.

The Committee's Comments *

The paramount purpose of the proposed act is to set up an orderly system of appropriation of water based upon the rule of priority of right. The Committee finds it would be necessary: (1) to determine, define and protect existing common-law uses; (2) to place limitations upon unused common-law rights as now recognized in this state and subordinate them to appropriation rights; (3) to allow a common-law owner of unused water rights a means of recovery for such damages as he is able to prove he has suffered by any injury or impairment of his property or of any right to initiate a later use of water; (4) to deny injunction relief to common-law owners who have not initiated any use of water or who have not begun the construction of any diversion works; (5) to authorize injunction relief for the protection of an appropriator under the act as against a common-law owner who seeks to initiate a common-law use after the effective date of this act; (6) to clothe a central state administrative agency with the authority to control the appropriation of water as directed by the act and in conformity with the legislation now in practical operation in many states; (7) to establish principles for appropriation and use of water with a view toward conservation of this natural resource for the greatest benefit of its people and to prevent waste of water by permitting its flow on toward the ocean.

The Committee believes that the 1889 statute (Laws of 1889, ch. 105), which provides procedure for condemnation of the right to take water from a stream for purposes of procuring or furnishing water for irrigation is unworkable.

Where water is proposed to be diverted from a stream the prospective damages to lower riparian owners in most instances are largely speculative. In the case of projects using water supplies regulated by storage reservoirs, such as is being considered on the North Fork of the Solomon River at Kirwin, and at other locations as shown in the report of the Kansas State Board of Agriculture for December 1944, the lower riparian owners are more likely to be actually benefited rather than injured. Flood discharges will be reduced by storage in the reservoirs and low flow of streams will be augmented by the return water from irrigated lands in the same manner as in Nebraska, described to the Committee by Mr. John L. Riddell in his remarks quoted on page 619 of this report.

At the same time, when any quantity of water is taken from a stream and consumed, as for example, 40,000 acre-ft. from the North Fork of the Solomon River at Kirwin, the total volume of runoff not only of the Solomon River but of the Kansas, the Missouri and the Mississippi rivers will be diminished by a certain amount.

It would be wholly impractical to make parties to an action the owners of all riparian land below a project to acquire whatever rights they might have which would be affected, even if the statute were amended. It is their

* At this point in the original report the Committee included a draft of the bill which they recommended to the 1945 Legislature. The legislation in its final form appears on page 626.

suggestion therefore, that this statute, being Sections 42–109 to 42–118, inclusive, G.S. Kansas, 1935, be repealed. A lower riparian owner who believes he is injured as a result of the diversion of water by an upper appropriator is provided a remedy at law in an action for damages and is entitled to recover for such injury as he can prove.

In proposing the repeal of Section 42–3,109, G.S. Kansas, 1935, and recommending in lieu thereof the procedure in Section 8, the Committee takes note of the peculiarities of the problem and the steps taken by other states to meet it. Streams along or in the valleys of which appropriations of water are made are not limited to the boundaries of a county. Most of them pass through several counties, and even several judicial districts. To be effective, priorities of appropriation should be determined along the entire stream in one proceeding.

Western states have been faced with the problem and have met it in this manner, as pointed out in the body of this report. Most recent of the states to move in this direction was Utah. In 1943 the legislature of that state amended earlier statutes to make it mandatory for the district court to refer to the state engineer for investigation and proposed determination, all water suits which involve an adjudication of the rights to a major part of the water of any river system.

The Committee recommends that the 49 water appropriation applications for allotments of water which were filed with the chief engineer subsequent to May 5, 1941, should be validated with priority dates as of the dates of their respective filings and that such pending applications should be further processed under and in accordance with the provisions of this act. Were that not done the applicants would find it necessary to refile under the new legislation, resulting in inconvenience to them and possible confusion, and additional work for the department.

Finally, the Committee believes that the artesian well statutes are of no operative use of any consequence and that such statutes are neither necessary nor desirable in the light of present-day knowledge of ground water supplies; that the ineffective provisions for artesian well boards and supervisors may be conflicting or at variance with a centralized state administration of water appropriations, and that these should be repealed by a separate bill for such purpose.

Acknowledgments

The Committee desires to express its appreciation to the many persons, water users and others, who have aided the Committee by participating in its deliberations or in the preparation of this report.

Special acknowledgment is due the following persons for valuable help given the Committee:

Spencer L. Baird, District Counsel, U.S. Bureau of Reclamation
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Horace H. Watkins, Assistant Attorney General

THE NEW KANSAS LAW

The material which follows is the law enacted by the 1945 Legislature and signed by the Governor of Kansas. It became effective June 28, 1945.

Sections 82A–701 to 82A–722, 1945 Supplement to the General Statutes of Kansas

AN ACT to conserve, protect, control and regulate the use, development, diversion and appropriation of water for beneficial and public purposes, and to prevent waste and unreasonable use of water, and amending sections 24–903, 42–308, 74–509c, 74–509e, and 74–510, of the General Statutes of 1935, and repealing said original sections and also repealing sections 24–904, 42–109, 42–110, 42–111, 42–112, 42–113, 42–114, 42–115, 42–116, 42–117, 42–118, 42–301, 42–305, 42–3,109, 74–509b and 74–509d of the General Statutes of 1935.

Be it enacted by the Legislature of the State of Kansas:

SECTION 1. *Definitions.* When used in this act the following words shall have the following respective meanings:

(*a*) "Person" shall mean and include a natural person, a partnership, an organization, a corporation, a municipality and any agency of the federal government.

(*b*) "Chief Engineer" means the chief engineer of the Division of Water Resources of the Kansas State Board of Agriculture.

(*c*) "Domestic Uses" means the use of water for household purposes, the watering of livestock, poultry, farm and domestic animals and the irrigation of gardens and lawns.

(*d*) "Vested Right" means the right to continue the use of water having actually been applied to any beneficial use at the time of the passage of this act or within three years prior thereto to the extent of the existing beneficial use made thereof, and shall include the right to take and use water for beneficial purposes where a person is engaged in the construction of works for the actual application of water to a beneficial use at the time of the passage of this act, provided such works shall be completed and water is actually applied for such use within a reasonable time thereafter.

(*e*) "Appropriator" means and includes a person who obtains a permit from the chief engineer authorizing him to divert and apply an allotted quantity of water for a designated beneficial use and who makes actual use of the water for such purpose.

(*f*) "Appropriation" means and includes an amount of water authorized and allotted by the chief engineer for a designated beneficial purpose within specific limits as to quantity and rate of diversion and withdrawal.

SEC. 2. All water within the state of Kansas is hereby dedicated to the use of the people of the state, subject to the control and regulation of the state in the manner herein prescribed.

SEC. 3. Subject to vested rights, all waters within the state may be appropriated for beneficial use as herein provided. Nothing in this act contained shall impair the vested right of any person except for nonuse.

SEC. 4. As soon as practicable after the passage of this act, the chief engineer or his authorized representative

shall proceed with the necessary steps to gather data and other information as may be essential to the proper understanding and determination of the vested rights of all parties using water for beneficial purposes other than domestic. Such observations and measurements shall be reduced to writing and made a matter of record in his office.

The chief engineer shall then make an order determining and establishing the rights of all persons making beneficial use of water on the effective date of this act and the then extent of their uses and shall notify all such water users as to the contents of such order. Service of such notice shall be deemed complete upon depositing such notice in the post office as registered mail addressed to such water user at his last known post-office address. The order of determination of the chief engineer shall be in full force and effect from the date of its entry in the records of his office unless and until its operation shall be stayed by an appeal therefrom by such user to the district court of the county in which the point of diversion of such use is located. All such appeals from the order of the chief engineer must be filed within sixty days after posting and mailing of the notice of such order of determination.

SEC. 5. No person shall have the power or authority to acquire an appropriation right to water without first obtaining the approval of the chief engineer: *Provided, however,* That this section shall not apply to persons using water for domestic uses.

SEC. 6. The chief engineer is hereby authorized and empowered, and it is hereby made the duty of such officer, to control, conserve, regulate and allot the water resources of the state for the benefits and beneficial uses of all of its inhabitants in accordance with the rights of priority of appropriation.

SEC. 7. Section 24–903 of the General Statutes of 1935 is hereby amended to read as follows: Sec. 24–903. (*a*) Surface or ground waters of the state may be appropriated as herein provided. Such appropriation shall not constitute absolute ownership of such water, but shall remain subject to the principle of beneficial use. (*b*) Where appropriations of water for different purposes conflict they shall take precedence in the following order, namely: Domestic, municipal, irrigation, industrial, recreational and water power uses. (*c*) As between appropriators, the first in time is the first in right. The priority of the appropriation shall date from the time of the filing of the application therefor in the office of the chief engineer. (*d*) Appropriation in excess of the reasonable needs of the appropriators shall not be allowed.

SEC. 8. The chief engineer shall determine the priorities of right to the use of the waters of the state, as to all persons who have since May 5, 1941, and who shall hereafter make application for a permit or certificate to divert, appropriate and use water. An appeal may be taken from any decision or order of the chief engineer to the district court in the county of his official residence or in the county in which the point of diversion is located. All such appeals must be filed within thirty days after date of such decision or order.

SEC. 9. Every person intending to acquire an appropriation right to any of the waters of the state for beneficial use other than domestic may do so only by making an application to the chief engineer for a permit to make such appropriation. The application shall set

forth (*a*) the name and post-office address of the applicant, (*b*) the source from which said appropriation shall be made, (*c*) the amount of water sought, (*d*) the location of the proposed works for the diversion and use of the water, (*e*) the estimated time for the completion of the works, (*f*) the estimated time for the first actual application of the water for the beneficial use proposed, (*g*) if for irrigation use, a description of the land to be irrigated by designating the number of irrigable acres in each forty-acre tract or fractional portion thereof, (*h*) if for municipal water supply, it shall give the present population to be served and the estimated future requirements of the city, (*i*) any additional factors which may be required by the chief engineer.

Such application may be filed before commencing the construction, enlargement or extension of any works for the diversion and use of water and before or after performing any work in connection with the same.

SEC. 10. Upon receipt of the application it shall be the duty of the chief engineer to endorse thereon the date of its receipt and assign a number to the same. If upon examination the application is found to be defective, inadequate or insufficient to enable such official to determine the nature and amount of the proposed appropriation, it shall be returned for correction or completion or for other required information. No application shall lose its priority of filing on account of such defects, provided acceptable data, proofs, maps, plats, plans and drawings are filed in the office of the chief engineer within thirty days following the date of the posting of the return of such application or such further time not exceeding one year as may be given by the chief engineer.

All maps, plats, plans and drawings shall conform to prescribed uniform standard as to materials, size, coloring and scale and shall show: (*a*) the source from which the proposed appropriation is to be taken, (*b*) all proposed dams, dikes, reservoirs, canals, pipe lines, power houses and other structures for the purpose of storing, conveying or using water for the purpose approved and their positions or courses in connection with the boundary lines and corners of the lands which they occupy. Land listed for irrigation shall be shown in government subdivisions or fractions thereof. Default in the refiling of any application within the time limit specified shall constitute a forfeiture of priority date and the dismissal of the application.

SEC. 11. It shall be the duty of the chief engineer to approve all applications made in proper form which contemplate the utilization of water for beneficial purpose, within reasonable limitations, provided the proposed use does not conflict with an existing use, and provided the proposed use does not prejudically and unreasonably affect the public interest. If it is determined that the proposed use of the water sought to be appropriated would impair vested rights, prior appropriations or be detrimental to the public interest, it shall be the duty of the chief engineer to enter an order rejecting such application or requiring its modification to conform to the public interest to the end that the highest public benefit and maximum economical development may result from the use of such water.

SEC. 12. Upon approval of the application the chief engineer shall notify the applicant to that effect and authorize him to proceed with the construction of the proposed diversion works and to take all steps required to apply the water to the approved and proposed beneficial use and otherwise perfect his proposed appropriation. An application may be approved for a less amount of water than that requested and it may be approved upon terms, conditions and limitations deemed necessary for the protection of the public interest. An applicant shall be entitled to proceed with construction of diversion works and with the diversion and use of water in accordance with the approval and limitations prescribed by the chief engineer and shall not be restrained or enjoined from proceeding with the construction of diversion or other authorized works or from the diminution of water supply, by any common-law claimant: *Provided* That common-law users with determined vested rights as herein defined, may enjoin diversions which impair such uses.

If the application is refused, the chief engineer shall so notify the applicant, and it shall be unlawful for such applicant to take any steps toward the construction of the proposed diversion works or to divert or use any such water, so long as the refusal shall continue in force, if such proposed diversion or use affects an appropriation right. Any person who proceeds subsequent to the effective date of this act, to construct and maintain diversion works without the approval of the chief engineer being first obtained, or who initiates a diversion or use of water from any source for any purpose other than domestic, without such approval, or who proceeds other than as authorized by the approval of his application may be enjoined in any court of competent jurisdiction, when an appropriation right is being affected.

SEC. 13. The chief engineer shall limit the time for the perfecting of an appropriation to a reasonable period within which the proposed works can be completed by expeditious procedure, and he shall for good cause shown by the applicant allow an extension of time.

SEC. 14. Upon the completion of the construction of the works and the actual application of water to the proposed beneficial use within the time allowed, the applicant shall notify the chief engineer to that effect. The chief engineer or his duly authorized representative shall then examine and inspect the appropriation diversion works and, if it is determined that the appropriation diversion works have been completed and the appropriation right perfected, in conformity with the approved application and plans, the chief engineer shall issue a permit or certificate of appropriation in duplicate. The original of such certificate or permit shall be sent to the applicant and shall be recorded with the register of deeds in the county or counties wherein the point of diversion is located as other instruments affecting real estate, and the duplicate shall be made a matter of record in the office of the chief engineer.

SEC. 15. All applications for the appropriation of water to beneficial use as filed with the chief engineer, subsequent to May 5, 1941, and all processing, proceedings and certificates pertaining thereto are validated to same extent as if filed after the effective date of this act, but with priorities as of the dates of filing of applications. All sub-

sequent processing of such applications as are still pending and undetermined shall be further considered and processed as provided in this act.

SEC. 16. If any appropriation, or the construction and operation of authorized diversion works results in an injury to any common-law claimant, such person shall be entitled to due compensation in a suitable action at law against the appropriator for damages proved for any property taken. An appropriator who has acquired a valid right under this statute may prevent, by injunction, a subsequent diversion by a common-law claimant of private rights without being required to first condemn possible private rights. An appropriator shall have right to injunction relief to protect his prior right of beneficial use as against use by an appropriator with a later priority of right.

SEC. 17. All appropriations of water must be for some beneficial purpose. The right of the appropriator and his successors to the use of water shall terminate when he ceases for three years or more, to use it for the beneficial purposes authorized in his permit or certificate.

SEC. 18. Section 42–308 of the General Statutes of 1935 is hereby amended to read as follows: Sec. 42–308. Any right of appropriation shall exist and continue only by the exercise thereof in a lawful manner. The failure of the appropriator continuously to apply such water to lawful and beneficial uses, for a period of three years, without due and sufficient cause shown for such failure, shall constitute a forfeiture and surrender of such right.

SEC. 19. The chief engineer shall compile information concerning the condition, location and extent of every water use and water appropriation other than domestic uses. Before any water appropriation shall be declared forfeited and surrendered the appropriator shall be notified in writing to appear at a designated time and place and show cause why his water appropriation should not be declared forfeited.

Such notice shall contain the following information in addition to the time and place of hearing: (1) a description of the water appropriation in question, giving its number and date of priority; (2) the substantial location of the point of diversion; (3) the general description of the lands or places where such appropriated waters were used; (4) a statement that unless due and sufficient cause be shown the water appropriation will be forfeited and canceled. Such notice may be served by registered mail and shall be posted at least thirty days before the date of the hearing and shall be sent to the last known address of the appropriator or his successor.

The verified report of the chief engineer or his authorized representative shall be prima facie evidence of the forfeiture and surrender of any water appropriation. An appeal may be taken within sixty days from the date of any decision of the chief engineer declaring the forfeiture and cancellation of any water appropriation to the district court of the county in which the point of diversion for such appropriation is located.

SEC. 20. Section 74–509c of the General Statutes of 1935 is hereby amended to read as follows: Sec. 74–509c. Whenever the rights for the use of waters of the state shall have been adjudicated by any court, the division of water resources with the aid of its chief engineer and other officers and employees, shall aid in the distribution

of such water according to such decree and shall distribute the water among the several ditches or water users pursuant to the decree; and shall have the power to open, close or adjust the headgates and regulate the controlling works of any ditch or structure, or cause the same to be opened, closed, adjusted and regulated so as to make a distribution of the water in conformity with the decree.

SEC. 21. Section 74–509e of the General Statutes of 1935 is hereby amended to read as follows: Sec. 74–509e. The clerk of any court of this state in which a decree shall be made fixing the rights pertaining to ditches or water users to water, shall within ten days after such decree shall have been entered, forward to the chief engineer of the division of water resources, by registered mail, a certified copy of such decree.

SEC. 22. Section 74–510 of the General Statutes of 1935 is hereby amended to read as follows: Sec. 74–510. It is hereby made the duty of all departments of the state government and of the state university and state agricultural college and its branches and experiment stations to furnish information and assistance to such chief engineer upon his request therefor.

SEC. 23. This act shall be construed liberally to effectuate the purposes hereof, and the enumeration of specific powers in this act shall not operate to restrict the meaning of any general grant of power contained in this act or to exclude other powers comprehended in such general grant.

SEC. 24. If any clause, sentence, paragraph, section or part of this act shall be adjudged by any court of competent jurisdiction to be invalid, such judgment shall not affect, impair or invalidate the remainder thereof, but shall be confined in its operation to the clause, sentence, paragraph, section or part thereof directly involved in the controversy in which such judgment shall have been rendered, and it shall be presumed that the legislature would have enacted this law with the section, subsection or clause held to be invalid, omitted.

SEC. 25. Sections 24–903, 24–904, 42–109, 42–110, 42–111, 42–112, 42–113, 42–114, 42–115, 42–116, 42–117, 42–118, 42–301, 42–305, 42–308, 42–3,109, 74–509b, 74–509c, 74–509d, 74–509e and 74–510 of the General Statutes of 1935 are hereby repealed.

SEC. 26. This act shall take effect and be in force from and after its publication in the statute book.

Surplus OCD Fire Pumps

On June 20, 1945, all members of the Association were mailed a communication concerning the possible purchase of OCD fire pumps. Anyone interested in such purchase and who may have missed this mailing is advised to address directly:

The Director of OCD Property
Department of Commerce
Washington 25, D.C.
Telephone, DISTRICT 2200

Interpretation of Natural Fluctuations of Ground Water in Terms of River Flow

By Carroll F. Merriam

Pennsylvania Water & Power Co., Baltimore, Md.

Presented on Nov. 9, 1944, at the Four States Section Meeting, Philadelphia, Pa.

THERE has been in late years concern about the lowering of the water table in populous areas where ground water is depended upon for an important part of the water supply. Considerable survey work has already been done and many areas are intensively covered by wells, or measuring points, relatively closely spaced; so closely spaced that wells penetrating a specific aquifer rise and fall very much in unison. To measure the changes that are taking place it is merely necessary to strike an arithmetic average of numerous wells. As long as a reasonable number of wells are included it makes little difference how many and which ones are averaged. Should the record of a single well be lost or discontinued, this resulting error is minimized by the mass of data still remaining.

In contrast, the situation with regard to natural fluctuations is that even in the regions where the study is relatively intensive there is little expectation that even two wells will reach the same aquifer. Some wells will strike perched water tables; some may be so close to stream beds that they become substantially river stage recorders, some may be so close to the spring line that they never rise beyond a given level, no matter how wet the season may be; some in fact may be in compact soil so that comparatively little addition of water may raise the table several feet; whereas others may be in gravel so loose that the entire variation from spring to fall may be only about 1 ft.

Under these conditions, which defy rational analysis, and because of the paucity of data covering an extensive area, it becomes obvious that mere arithmetic averaging is not sufficient. It can readily be seen that a well having normally a wide seasonal range would exert an inordinately strong influence over the average. Some wells have been found entirely unsatisfactory, since their behavior bears no relation to the general pattern of the others. A further complication lies in establishing a zero for the gage. Initially, it was decided that the actual elevation on a specified date, which happened to be about at the end of a protracted drought, would be considered the zero for all wells. At the outset this plan was satisfactory, but the question arose as to how additional wells could be cut in without disturbing the average. Loss of wells which were discontinued or had to be dropped for one reason or another added to the difficulties of getting a reliable arithmetic average.

By purely empirical means, the engineers of the Pennsylvania Water &

Power Co. have reduced the readings of each well to common terms by the development of rating curves, so that weighted averages can be derived with minimum effect caused by taking on new or dropping old wells.

In measuring the actual fluctuations observed in critical areas, it is impossible to separate the effect of pumping from what would have happened if there had been no pumping at all. It is entirely possible that a serious lowering of water table might apparently be caused by pumping, whereas conceivably the drop could for the most part have resulted from natural causes. At the same time water levels may apparently be coming back to normal in spite of pumping, but there is no way of being sure that the recovery was not mainly the result of a general rise in the natural ground water levels.

So far, no claim can be made that the observations of natural fluctuations have been carried to the point of practical application to problems in the critical areas, but it can readily be appreciated that it will never be possible to get the fullest value from observations in these areas or complete assurance against misleading results until at least some attempt is made to correlate these observations with corresponding measurements in areas where the water table is undisturbed by extensive use.

One of the great difficulties in interpreting ground water is to translate the measurements into terms of volume. When dealing with artificial fluctuations some relation can be found experimentally between intensive pumping and the drop in the static levels of wells at various nearby points. On the other hand, when studying the natural fluctuations in a river basin having a drainage area of approximately 27,000 sq.mi. and a decidedly diverse topography, this problem has to be approached in an entirely different way.

Time does not permit an explanation of the method followed, but the essential thing is that through careful comparison with river flow there has been deduced a fair, but for a special reason, conservative estimate of the quantity of water released to the river corresponding to a given amount of drop in the ground water. Furthermore, the natural rate of drop without additions from rainfall has likewise been approximated and so, by combining both volume per foot and rate of decline in feet per week, it is possible to estimate the ground water hydrograph. No great amount of accuracy is claimed, but this conservative estimate based upon the average ground water has been useful in forecasting minimum river flow which could occur for approximately a month or two following the date of observation. This knowledge has proved to be a valuable guide in the scheduling of steam equipment for maintenance by giving assurance as to whether this equipment will or will not be needed because of low river flow before some definite date in the future.

In effect, it has been found that the ground water in the Susquehanna Valley behaves as though stored in a surface reservoir having an area of about 300 sq.mi. and a normal seasonal variation in level of between 4 and 5 ft., and as though provided with a notched outlet so calibrated that the rate of outflow depends solely upon the elevation of water surface. Consequently, when this imaginary elevation, or ground water index, is determined, the rate of discharge for weeks in advance may be definitely forecast.

A number of interesting facts have been deduced. The total volume released annually by reason of the normal decline between spring and fall is a relatively small proportion of the total annual flow of the river. Consequently, it is obvious that there is not sufficient storage to alter to any marked degree the enormous flood volumes encountered when the river goes on the rampage. In other words, on the Susquehanna knowledge of ground water itself has little practical value from the standpoint of flood warning. In other rivers the situation may be decidedly different, but at least in a basin which is to such a large extent mountainous upland, the ground storage seems to have little regulating effect upon the floods.

The next disappointment in this study was the discovery that with the seasonal release of water from ground storage equal to only about 4 per cent of the total flow for the year, unusually high ground water levels in the spring do not presage good river flow in the following dry season. There is not enough carry-over to make good any marked deficiency of rain in the meantime.

Another revelation was that there seems to be relatively little variation in the heights to which the index rises in the spring. The ground storage seems to get full and that is all there is to it; the rest spills away. On the other hand, there is considerable difference in the fall season and here is where the value of this work lies.

From the point of view of power development the incremental value of any water that can be added to the stream increases enormously as the river flow diminishes. Consequently, not only does the assurance of even a small amount of water in a dry season represent the equivalent of perhaps a quarter million dollars worth of coal, at a time when the more expensive steam plants would have to be run, but the knowledge that the flow will not fall below a definite minimum can be translated into steam capacity which would otherwise have to be made ready for service.

Power companies are not the only ones interested in the low flow of a river. Although many municipalities are dependent upon stream flow and might suffer from deficient water, one of the most serious aspects of low flow is the question of stream pollution and navigation. So important are these questions that already a number of regulating works have been constructed to provide storage which can be released during periods of extreme drought. Many flood control dams provide a conservation pool to be drawn upon to bolster the minimum flow. It takes but little imagination to see the importance of any means which will forecast the need for augmenting the natural discharge of these streams, and it is only logical to suppose that in the future the schedule for operating the conservation pool which is now determined by compromise between flood and low water requirements may actually be modified advantageously according to the forecast of the prospective needs.

Conclusions

There is good reason to believe that the reduction of the ground water index to a quantitative measure of the amount of water retained in the water table is the key to many of the uncertainties met in attempting to analyze the operation of the hydrologic cycle. We already have experimented and found that by taking into consideration the

water stored in the ground, the relation between rainfall and runoff becomes far more definite than shown by the usual scatter diagrams. By determining a more clear-cut relation between those two elements, a far better estimate of the rate of loss through evaporation, transpiration, etc., and a study of the behavior of this loss throughout the twelve months of the year can be made.

The results of this experimentation are expressed graphically in the accompanying figure which shows samples taken at three-month intervals. It is well known that even on an annual basis plots of runoff vs. rainfall only too frequently result in scatter diagrams from which it is difficult to establish satisfactory relations between the two variables. In attempting to break the year down by months the situation is even more hopeless, as indicated by the upper row of graphs in which no correlation is evident.

To some extent this confusion is caused by the fact that there is considerable time between the precipitation and the resulting runoff, particularly when a severe storm strikes near the end of one month and the major part of the river flow is held over to the following month. Accumulation of snow is responsible for the carry-over of several months so that analysis of the complex interrelations becomes decidedly difficult. Some help can be secured by mass curves of weekly values so that approximate corrections can be made for the time delay and the picture becomes somewhat more rational, as shown by the middle row of graphs.

To complete the analysis, if an estimate can be made of the ground water in storage at any time, the losses can be evaluated and the amount of snow which eventually appears as runoff can be taken into account. The result is that the relation between rainfall and that part of rainfall which will eventually appear as runoff becomes much clearer.

It may be argued that the straight lines shown in the bottom row could have been drawn to fit the points more closely. They are located as they are in order to have them "nest" with the intermediate months which, for the sake of brevity, are not included. Taken as a whole, the graphs indicate very strikingly the minimum rainfall that must be exceeded each month in order that there be any addition to the potential runoff. Below this amount the ground normally loses more moisture than is supplied by rain.

Although it is too early to draw definite conclusions, it seems quite likely that by evaluating this "missing link" in the chain, it will be possible to lay the foundation for a sort of water accounting which will give information on two important elements in the forecasting of stream flow. One of these is the snow storage, which is at present laboriously estimated from field snow surveys, and the other is a curious phenomenon which probably explains the apparently erratic behavior of the stream during the latter part of the summer. For a long time the Susquehanna refuses to respond to repeated rain storms until eventually a time comes when there is a distinct change in the rainfall-runoff relation. Preliminary studies, using ground water storage to account for the water which is delayed in reaching the stream (about 40 per cent of the total river flow apparently passes through the ground water stage), indicate that even when there is no rain, the summer losses continue to go on without any marked withdrawal from the water

APPLICATION OF GROUND WATER INVENTORY
TO ANALYSIS OF RELATION BETWEEN RAINFALL AND RUNOFF

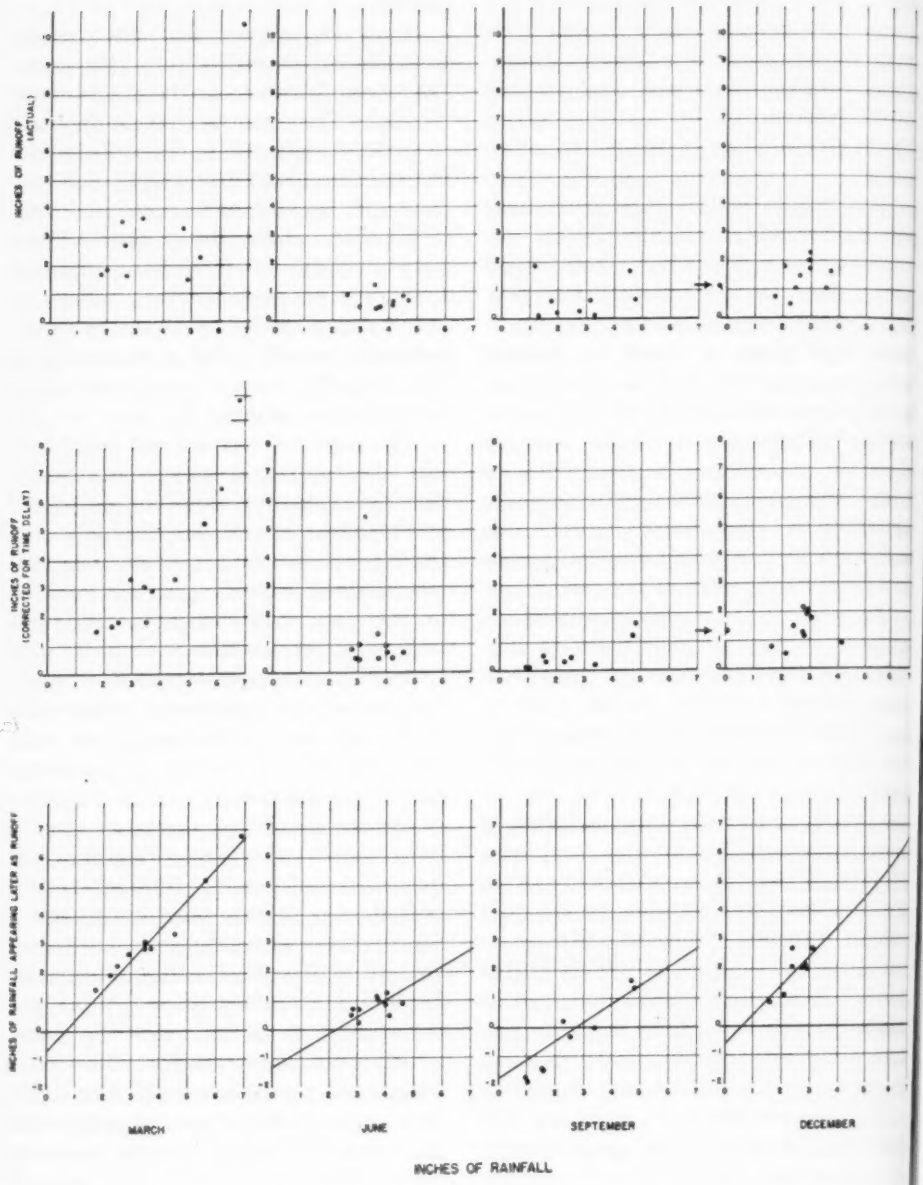

table other than that which drains away normally to the stream regardless of season. So far, it has been impossible to detect any difference between the summer and winter ground water hydrograph. Even when there is no rain and, as far as we have been able to see, no measurable evidence of water being drawn upward from the water table (although this must take place to a limited extent where roots of trees extend down to the water table), this loss goes on, but apparently is derived from a reduction in the moisture content of the soil itself. The interesting thing is that no marked amount of surface flow occurs until after this loan is repaid. It would seem, therefore, that even though the actual ground water level may be a poor indicator of the danger of flood, nevertheless the moisture deficiency in the soil above the water table, which must be restored before floods can occur, may possibly prove a better warning. In any case, there seems to be a fruitful field for further study.

It should be emphasized that ground water observations, regardless of the purpose for which they are made, are not directly translatable into useful information, but are only of value when observed over a period of time sufficient to build up a background from which conclusions may be drawn. Do not wait until the need arises and then expect in a short time to get results. Now is the time to establish at least some program of observation so that the trends over a period of years can become sufficiently well defined to be of value. It was ten years from the time that observations first began in Pennsylvania until anything of practical value was obtained.

There is reason to believe that natural ground water observations in abandoned wells and test holes have an important bearing on the operation of multi-purpose dams. Furthermore, there is good prospect that a better knowledge of the quantity of water thus stored in the earth will prove to be the key to many studies concerning the disposition of rainfall as it finds its way either into the streams or back to the clouds again. The first step in this direction must be observation for a sufficient period of time in anticipation of the need to provide the foundation of basic data.

Acknowledgments

The author wishes to acknowledge the splendid co-operation of the U.S. Geological Survey in making possible the continuation of the observations of the Pennsylvania wells since this work was first undertaken in 1931.

Municipal and State Exemptions From Federal Excise Taxes

The latest information concerning (1) federal excise taxes imposed on articles and services purchased by municipal and state governments, (2) how these governments may secure exemptions therefrom, and (3) all of the Bureau of Internal Revenue rulings and interpretations affecting these exemptions, is obtainable in Special Bulletin CC, published by the Municipal Finance Officers Association of the United States and Canada, 1313 East 60th St., Chicago 37. The four-page leaflet is dated June 1945 and is priced at 25¢.

Decision Concerning Radio Facilities

By Charles F. Meyerherm

Cons. Elec. Engr., New York, N.Y., and Member, Public Water Supply Group, Committee 4, Panel 13, Radio Technical Planning Board

A contribution to the Journal

UNDER date of May 21, 1945, the Federal Communications Commission issued a report of proposed allocations in the range below 25,000 kc. (kilocyles) and under date of May 25, 1945, a report of allocations in the range of from 50,000 to 30,000,000 kc.

The points to be stressed in connection with the present status of emergency radio communication development are:

1. *The new frequency allocations embody provisions for water works emergency radio communications service.*

2. *The water works industry as an industry should be prepared to make use of its reasonable share of the channels provided for the so-called "power utility" group.*

3. *Individual water works departments and companies should "blueprint now" an emergency radio communication system which will, under every foreseeable emergency, provide the essential communication facilities which their particular system may require.*

Portions of the section of the FCC report on "Special Services" (which apply to the water and other utilities) and of the commission's "News Release" of May 17, 1945, are reproduced herewith.

"Committee 4 of Radio Technical Planning Board, Panel 13, objected to the small number of channels (20) which the commission proposed to allocate between 25 and 300 mc. (megacycles) for the mobile service of the utilities. Committee 4 further pointed out that the 20 channels allocated were required to be shared by the power utilities, petroleum industries and certain other industries and utilities. The original request of the power utilities was for a total of 36 channels for the mobile services in the 30–300-mc. range, and the petroleum industries requested a total of sixteen channels in this range, making a combined total of 52 channels requested by these two industries. It was urged at the oral argument that, while the power utilities have no objection to sharing the frequencies, there are certain important areas where geographical separation of the power and petroleum industries does not exist and that therefore it would be difficult, if not impossible, for the commission to provide for the radio needs of both industries in these areas on the 20 channels proposed by the commission in the 30–300-mc. range.

"In view of the foregoing, the commission has made some changes in the allocations for the electric, gas, water and steam utilities. In the 25–30-mc. band, twelve channels with a channel width of 25 kc. are provided for. In the 30–40-mc. range, provision is made for seven channels with a width of 40 kc. In the 104–108-mc. band, six channels with a width of 50 kc. are allocated. In the 152–162-mc. range,

six channels with a width of 60 kc. are provided for.

"In each case, these channels will be available not only for the electric, gas, water and steam utilities and the petroleum industry but also for other industries requiring similar radio service.

"The frequencies allocated for the utility and industry groups are as follows:

Frequency Band mc.	*Channels* no.
25–30	12
30–40	7
104–108	6
152–162	6

"The testimony at the hearing indicated that in general the emergency and the essential communication requirements of electric, gas, water and steam utilities are in the nature of a mobile radio service for which short distance communication only is needed. The frequencies which the commission has allocated to this service above 25,000 kc. should suffice for this purpose. It is realized, however, that communication over considerable distances may be necessary in some cases in connection with repair crews and supervisors in the field, between points along high-tension power lines, along pipelines and water supply aqueducts or over mountainous and desert terrain. Frequencies below 25,000 kc. may be required for this purpose, and the commission proposes to allocate such frequencies. While it is not possible at this time to designate specifically the frequencies which will be assigned for this purpose, it is anticipated that, in so far as possible, frequencies will be allocated for use by the electric, gas, water and steam utilities in accordance with the RTPB request. These frequencies will also be available to the petroleum industry and other industries having similar communication requirements."

It will be noted from these excerpts that the FCC proposes to allocate to the electric, gas, steam, water, petroleum and other interests *as a group*, five channels below 25,000 kc. and that it has definitely allocated to this *group* 31 channels above 25,000 kc. In the latter range no specific channel frequencies have as yet been designated and in the "News Release" it is stated that these allocations will be ordered to take effect service by service, with the commission taking into account, among other factors, the results of the Inter-American conference at Rio de Janeiro, which is scheduled for this fall.

With only a limited number of channels available to meet the demands of five or more utilities, it is evident that there will be few, if any, vacant channels in these frequency ranges even in the early stages of postwar emergency radio development. This, therefore, means that water works systems should begin to plan their radio communication systems *now*. They should begin thinking about how far and over what types of terrain they will have to transmit messages, where their fixed transmitters will have to be located and how many mobile units they will require. With this information available from all of the interests that expect to use radio in a given area, the available channels can be assigned to the best advantage of all concerned. It is quite evident that late-comers may be at a distinct disadvantage in finding channels suitable to their needs.

Readers are referred to "Application of the Public Water Supply Industry for Radio Channel Allocations," in the December 1944 JOURNAL, *p. 1285.*

Water Treatment at Ottawa, Ontario

By H. P. Stockwell Jr.

Asst. Water Works Engr., Ottawa, Ont.

Presented on Mar. 19, 1945, at the Canadian Section Meeting, Toronto, Ont.

THE treatment of a colored water involves problems differing somewhat from those met with in treating other types of natural water supplies, such as the relatively high coagulant dosage required and the large volume of sludge resulting therefrom; the fragility of the alumina-color floc and the important influence of pH on its formation; and the great reduction in chlorine demand following removal of the organic color content.

The Ottawa raw water has an average color of 40, alkalinity of 23 and pH of 7.1. The temperature ranges from 32°F. in winter to 85°F. in late summer. Because of the organic content, principally color substances, such water supplies have a considerable chlorine demand. The practice has been first to remove these chlorine-consuming substances by coagulation and then to add the greatly reduced requirement of chlorine to the colorless effluent. Before the provision of a modern filtration plant, the high chlorine dosage required was not conducive to a palatable supply and it was difficult to maintain residual chlorine in the distribution system with a moderate application of the chemical. The addition of ammonia to the chlorine treatment of this water by Joseph Race, in 1915, provided a more persistent residual with better germicidal action and made possible some reduction in chlorine dosage. This is stated to be the first application of the so-called "chloramine" process to a municipal water supply. Curves showing the rate of chlorine consumption at 50°F. for both types of treatment are shown in Fig. 1. It will be noted that there is a large initial demand followed by consumption at a lower rate, the net effect of the addition of ammonia to the process being to retard this secondary rate of consumption. Free ammonia in the raw water varies from 0.01 to 0.04 ppm. as nitrogen but there is no typical break-point in the residual chlorine-applied chlorine curve.

Color removal from such surface waters is effected under acid pH conditions provided by the acidic reaction of the coagulant. The optimum pH range differs with the coagulant used and in general the dosage is a function of the alkalinity of the raw supply. In many cases savings would be possible by the use of the minimum amount of coagulant together with some cheaper acid reagent for pH adjustment. It seems probable that the general public would not tolerate the use of mineral acid for this purpose. Carbon dioxide (carbonic acid) is both effective and acceptable to consumers but after filtration an increased amount of lime must be added for corrosion control, with a resultant increase in hardness of the plant effluent.

Claims have been advanced frequently that chlorination prior to coagulation of other colored waters, particularly those of higher alkalinity, re-

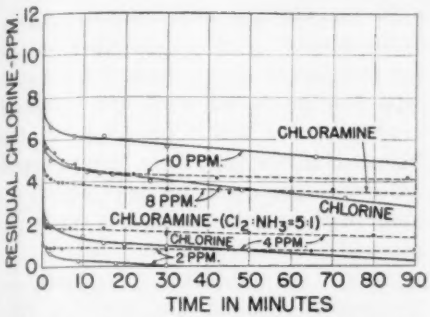

FIG. 1. Curves Showing Relationship Between Applied Chlorine and Residual Chlorine for Ottawa River Water

sults in better flocculation with considerable saving in coagulant. The effect of chlorine at this point in the treatment of Ottawa River water has been investigated. It makes possible a small reduction in alum dosage because of a slight increase in the acidity of the water. The maximum benefit in this respect is obtained almost immediately, there being no advantage in providing any considerable time interval between chlorination and coagulation. However, the saving in coagulant fails by a large margin to pay for the chlorine required and such treatment of this water supply cannot be justified on a cost basis.

Undesirable tastes in the tap water would originate, in part, in the raw supply and to a greater extent would be developed in the plant from sludge decomposition during the purification process. Control is effected by the application of 0.05 gpg. of finely ground activated carbon to the raw supply during the warm water period, which extends through August into September when the water temperature reaches a maximum of 80–85°F. and slight tastes are greatly accentuated. The carbon is added immediately prior to the coagulant in order that it will be well distributed throughout the sludge.

Further control of taste development in the plant is accomplished by frequent cleaning of all mixing tanks, settling basins and settled water conduits in accordance with the proposition that for a clean effluent, a clean plant is the first essential. Because of the relatively high alum dosages required to coagulate this water, averaging $2\frac{1}{2}$ gpg., large quantities of sludge settle throughout these various units and must be removed before decomposition takes place. Mixing tanks and settling basins are cleaned at three-week intervals during warm weather. This would have to be done more frequently were it not for the activated carbon treatment.

Settling of floc in the settled water conduits leading to the filters poses another rather important problem. Such deposits may become dislodged, as by the melting and breaking away of ice from the conduit walls with the spring thaw. Compact masses of sludge up to 2 or 3 in. in size pass on to the filters and form the familiar unsightly mud balls over the surface of the sand, as shown in Fig. 2. The cleanliness of the settled water conduits thus is an important factor in sand filter maintenance and this condition is controlled by periodical hosing out of this part of the plant.

It has been the practice at Ottawa to disinfect the sand filters at least once annually. This is most conveniently done by spreading a slurry of bleaching powder over the floor area of the empty wash water tank. After filling the tank, the total content is used to backwash the filter being treated, this amounting to more than double the normal quantity of wash water. The last portion of this bleach water is then allowed to remain in the

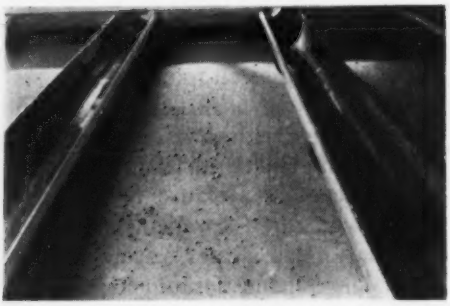

FIG. 2. Surface Mud Balls on Sand Filter Originating in Settled Water Conduit

filter overnight and is washed out the following morning.

Coagulation and filtration reduce the color of this water to 3, with a corresponding reduction in the chlorine demand. Over a period of thirteen years this treatment has also been 100 per cent effective in removing coliform bacteria. Application of chlorine to the plant effluent furnishes additional protection to the consumer. The chlorine dosage varies from 0.30 to 0.35 ppm., which provides a residual of from 0.05 to 0.15 ppm. after fifteen minutes of contact. Traces of chlorine persist for about 48 hours, which assures a slight residual at more remote parts of the distribution system. As in the case of the raw water, no breakpoint is apparent in the residual chlorine-applied chlorine curve.

The final use of chlorine in the operations of this department is in the disinfection of new and repaired mains. Contamination is almost sure to occur during such construction and repair work and disinfection following completion is essential. This is accomplished with chlorine fed by a portable panel-type Wallace and Tiernan chlorinator, mounted together with chlorine cylinders on a trailer chassis fabricated in the Civic Workshops (Fig. 3).

In the case of new mains, precautions against gross contamination of the pipe begin at the pipe yard where pipe lengths to be used are swabbed internally with a thin bleach wash, the two ends of the pipe then being capped with waterproof canvas bags which remain in place until the pipe is ready for assembly in the trench. After construction is completed, the main is thoroughly flushed and then a 100-ppm. solution of chlorine is applied and retained for 48 hours. Following this, the main is again flushed until the residual chlorine is normal. Samples for bacteriological tests are taken for four or five days after treatment and, if necessary, disinfection is repeated until satisfactory tests are obtained.

There are, in the Ottawa distribution system, some 23 under-water crossings, comprising mains passing under the Rideau River and Rideau Canal. It is conceivable that leakage inwards might occur following relief

FIG. 3. Portable Chlorinator Used For Disinfection of New Mains at Ottawa, Ont.

of water pressure in the mains. Such sections of mains must therefore be disinfected in a similar manner before they are replaced in service following such shut-down.

Our experience in the disinfection of mains has been that usually two treatments are necessary before the contamination is completely eliminated. This fact, in our opinion, justifies using the above method, which is somewhat more severe than that established as a tentative standard method by the American Water Works Association.

The use of chlorine in the various ways outlined, together with aluminum sulfate as a coagulant, activated carbon for taste control before sand filtration and lime for the control of corrosion after filtration results in a domestic supply of the highest bacteriological quality and physical cleanliness.

WPB—OWU Order U-1 as Amended June 2, 1945

Excerpts from WPB Letter 3081 follow:

An amendment of Utilities Order U-1 has been issued, effective June 2, 1945, eliminating all of the restrictions affecting the *expansion* of utilities facilities except for the construction of buildings. U-1 no longer gives priorities assistance for building construction materials, and requires specific approval on Form WPB-2774 where the cost of materials for the construction of a building would exceed $25,000.

No change has been made in the assignment of preference ratings except that paragraphs (b) and (c) forbid the use of this priorities assistance to get material for the construction of any buildings. New paragraphs (b) (5), (b) (6), (c) (3), and (c) (4) make it clear that the preference ratings and allotment symbol U-9 assigned in the order *may not be used* to obtain material for *major plant additions.*

The inventory controls of Order U-1 are now applicable only to material which a utility has acquired for use in maintenance, repair, as operating supplies or for minor plant additions. The controls on deliveries of paragraph (e) as modified by paragraphs (f) and (g) are still applicable to this class of material. A new paragraph (e) (2) provides the only control under U-1 with reference to materials required for major plant additions. Under this paragraph they may not be ordered in greater quantities or for delivery on dates earlier than required for an installation.

In determining the quantities of material and the delivery dates which a producer may specify on his orders in accordance with the provisions of this new paragraph (e) (2), consideration should be given to the availability of manpower for the proposed installation as well as to the delivery dates for materials required.

Paragraph (n) describes the uses of Form WPB-2774 (revised June 1) under the amended order. This application form is to be used for the following purposes only:

(1) Applications for priorities assistance for major plant additions and for materials for buildings.

(2) Applications for authorization to construct buildings where the net materials cost would exceed $25,000 for the building.

(3) Applications for upratings or other forms of special priorities assistance.

Special priorities assistance or upratings, or preference ratings for major plant additions or for building construction will not be granted unless the material is required to maintain the supply of essential utility services or to provide utility services on time for urgent requirements.

Boiler Feedwater Treatment

By M. C. Schwartz

Asst. Director, Engineering Expt. Station, Louisiana State Univ., Baton Rouge, La.

Presented on Oct. 18, 1944, at the Southwest Section Meeting, Austin, Tex.

IT is generally assumed that the need for purer boiler feedwater increases as the boiler operating pressure rises. The possible variations in the type of basic treatments used are numerous and will depend, for the most part, upon the composition of the raw water and upon the amount of boiler feedwater make-up. The treatment used should also be considered in relation to the boiler design. In any event, it is desirable to use the most economical system possible.

Effect of Boiler Scale

Many operating difficulties are experienced in high-pressure boilers, some of which have been previously discussed by the author (1), but the factor which still causes most boiler outages is the presence of intolerable amounts of sludge and scale (2). Most operators of high-pressure boiler plants are aware of this fact through their own experience. Operators of low-pressure boilers who have occasion to change to high-pressure boilers or who increase the rating of their boilers beyond normal are frequently unaware that the new conditions require an exactness of treatment previously unnecessary.

It therefore seems desirable to consider the effects of boiler sludges and scales on the outside wall temperature of the boiler tube as a function of the nature of the deposit, of the boiler pressure and of the rate of heat transfer at the point in question. It is obviously necessary to treat this problem in a general way because of the lack of exact and specific data for any given situation.

The rates of heat transfer under consideration are the maximum experienced, which usually are those attained in generating tubes and water-wall tubes closest to the maximum furnace temperature. Partridge (3), Cassidy (4) and Carmichael (5) indicate that values of the order of 50,000–100,000 Btu. per hour per square foot are in order. Data for the values of the thermal conductivity of scale (or sludge) are quite meager. Cassidy (4) indicates that values ranging from 2 to 12 Btu. per hour per square foot per °F. per inch are in order. A value of 300 Btu. per hour per square foot per °F. per inch has been selected for the thermal conductivity of the boiler tube metal. A value of 2,000 Btu. per hour per square foot per °F. for the water-steam film coefficient, as given by Cassidy (4), is used. Based on these data, a series of outside wall boiler tube temperatures are calculated as a function of boiler presure. The data are presented graphically in Fig. 1. A schematic representation of the temperature gradients occurring in Cases A and B of the data of Fig. 1, using 0.05 in. of scale, is shown in Fig. 2.

The effect of the scale is most evident particularly when it is considered dangerously unsafe to get near 900°F.

outside-wall boiler-tube temperature. As was indicated previously, the data cannot be taken literally because of the questionable significance of the numerical values used; however, the effects of variation in boiler pressure, rate of heat transfer, etc., are obvious. Whether or not the maximum thickness of the deposits which can be tolerated in a high-pressure boiler is $\frac{1}{1000}$ in., $\frac{1}{10}$ in. or some other figure, it is obviously unsafe to build up much deposit.

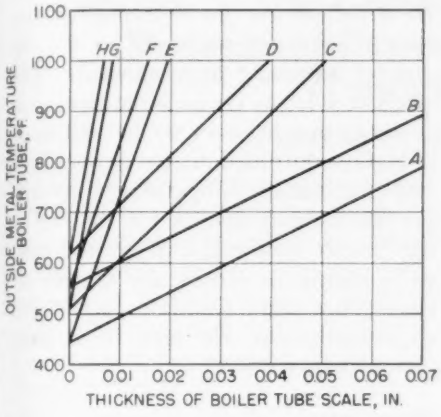

FIGURE 1

Key to Figure 1

A. $P = 175$-psi. gage
k scale = 12 Btu./hr./sq.ft./in.
$q = 50{,}000$ Btu./hr./sq.ft.

B. $P = 600$-psi. gage
k scale = 12 Btu./hr./sq.ft./in.
$q = 50{,}000$ Btu./hr./sq.ft.

C. $P = 175$-psi. gage
k scale = 12 Btu./hr./sq.ft./in.
$q = 100{,}000$ Btu./hr./sq.ft.

D. $P = 600$-psi. gage
k scale = 12 Btu./hr./sq.ft./in.
$q = 100{,}000$ Btu./hr./sq.ft.

E. $P = 175$-psi. gage
k scale = 2 Btu./hr./sq.ft./in.
$q = 50{,}000$ Btu./hr./sq.ft.

F. $P = 600$-psi. gage
k scale = 2 Btu./hr./sq.ft./in.
$q = 50{,}000$ Btu./hr./sq.ft.

G. $P = 175$-psi. gage
k scale = 2 Btu./hr./sq.ft./in.
$q = 100{,}000$ Btu./hr./sq.ft.

H. $P = 600$-psi. gage
k scale = 2 Btu./hr./sq.ft./in.
$q = 100{,}000$ Btu./hr./sq.ft.

Feedwater Treatment and Boiler Operation

In considering the nature of the boiler feedwater treatment to be employed, the question may be phrased as follows: How complete a system of purification and conditioning is actually needed? The designer is faced

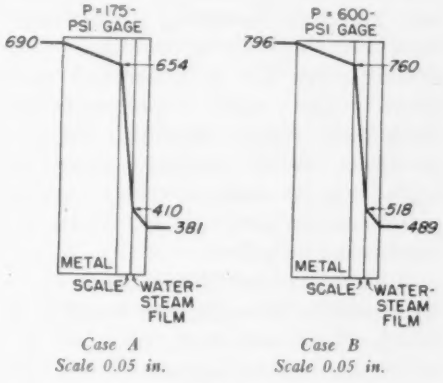

FIGURE 2

with a multitude of variations of clarification and softening methods. These are found, for example, in the newer type clarification and softening tanks, in the newer variations of hot process softening, in the newer combinations and materials for cation and anion exchange and in various combinations and methods for silica removal. As a rule, the designer probably selects a combination which previous experience indicates will be satisfactory because of somewhat similar conditions

between the old and new plants. Unfortunately, it has been considered unnecessary in most cases to test out the combined effects of over-all water treatment in an experimental boiler or experimental boiler tube under controlled rates of flow and heat transfer conditions.

To the lack of this type of experimentation, the author attributes the paucity of data on chemical phenomena taking place in the boiler; for example, a lack of information on the effect of alkalinity, phosphate concentration, calcium, magnesium and silica on the physical characteristics of phosphate sludge formed in boiler tubes. The effects of variations of certain boiler constituents, for instance silica, based on practical operating experiences have sometimes led to confusion. The answer may lie in controlled pilot plant boiler scale experimentation. Each water supply presents a different problem. When used as a source of high-pressure feedwater, it deserves consideration with relation to its behavior in the boiler.

A more practical illustration is a case with which the author is familiar in which two separate high-pressure boiler plants both operate their boilers at the same pressure and both have the same source of raw water as far as it is practically possible without their using the same intake. Neglecting the boiler and its operation, it would seem offhand that the same system of water treatment, or at least one of equal over-all softening, would be in order. Nevertheless, the water treatment systems used differ markedly in the degree of softening accomplished. The effect of silica as far as boiler operation is concerned appears to be different. A highly controlled degree of operation and examination of operating data may provide an explanation for the differing results obtained. In such a case, as in numerous others, the author believes pilot plant feedwater and boiler experimentation will lead to a satisfactory explanation.

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Reports of the Committee on Survival and Retirement Experience With Water Works Facilities

INTRODUCTORY STATEMENT

WATER was the first of the public utilities. Its facilities, while of a more permanent character than those of other public utilities, are nevertheless subject to mortality and replacement. The very fact that their period of usefulness is so long results in greater difficulty in securing factual data relating to actual life and mortality experience.

The importance of having available factual data relating to retirements of property and the cause of retirement is apparent when it is realized that the investment in water works facilities on the North American continent exceeds $5,000,000,000. The financial program of distributing the cost of property consumed in public service over its useful life can only be equitable when based upon a factual background.

Growing out of a realization of the importance of the above, the Board of Directors of the American Water Works Association in January 1941 authorized the creation of a special committee to undertake the collection of factual information which would indicate the actual lives of water works facilities. The committee initially consisted of the undersigned Executive Committee but was expanded to a membership of approximately 30 after a preliminary survey indicated that there was a keen interest in the subject throughout the membership of the Association. Acceptance of membership on the committee carried with it the obligation of assembling such data as were available in the plants represented by the members; it was indeed indicative of the potential value of the work that the acceptance of appointment to the committee was unanimous. The New England Water Works Association has appointed four of its members to serve with the A.W.W.A. committee.

It was the aim of the Executive Committee to have the list of cities studied include various sizes and types of plants from various sections of the country. In recognition of the extent to which obsolescence and inadequacy affect retirements of water works property, the selection of cities to be studied exemplifies rapid, slow and more normal growth. They were also selected for geographical distribution, ranging from Winnipeg and Ottawa in Canada to West Palm Beach, Fla., and Los Angeles, Calif. The systems studied include hard and soft water supplies from both underground and surface sources. The population range is from 5,000 to more than 2,000,000.

The number of facilities were divided between publicly- and privately-owned plants in approximately the same proportions as are the entire water works facilities on this continent. Every effort was made to make the

study comprehensive and well balanced.

The scope of the work is such that the program includes data relative to approximately one-eighth of all of the water works facilities installed on this continent.

In this issue reports covering Ottawa, Ont., and Des Moines, Iowa, appear. In later issues of the JOURNAL, reports will appear covering: Springfield, Mass.; Utica, N.Y.; Philadelphia, Pa.; Scranton, Pa.; Alexandria, Va.; Clinton, Iowa; Huntington, W. Va.; St. Marys, Pa.; Commonwealth, N.J.; Portland, Me.; San Francisco, Calif.; Winnipeg, Man.; Denver, Colo.; Jamaica, N.Y.; Babylon, N.Y.; Merrick, N.Y.; Norwich, N.Y.; Sag Harbor, N.Y.; Syracuse (Sub.), N.Y.; Rochester (Sub.), N.Y.; Clyde, N.Y.; West Palm Beach, Fla.; and St. Paul, Minn.

The work of this committee is factual, presenting data on survival and retirements, together with such explanatory notes regarding retirements as will assist in their interpretation. The committee does not offer conclusions but does present a vast amount of data not previously available.

The detailed work of the committee has been contributed by a large number of plants, both publicly and privately owned, at a large expenditure of time and energy and has been carried out under the general direction of E. H. Aldrich, Supervising Coordinator, working for the committee.

L. G. LENHARDT
DALE L. MAFFITT
REEVES NEWSOM
THOMAS H. WIGGIN
L. R. HOWSON, *Chairman*
Executive Committee of the Committee on Survival and Retirement Experience With Water Works Facilities

DEFINITIONS

The mortality studies of units of water works property made by this committee are based on the collection and compilation of the records of all units which were in service during some part of the entire history of the plant as of the date of the study.

Definitions of certain terms which have been used in this study are as follows:

Service Life—The service life of a physical unit of property is the period of time between the date when it was first put into service new as a part of the property and the date when it was retired from service.

Service Age—The service age of a physical unit of property is the period of time between the date when it was put into service new as a part of the property and the date of making the mortality study.

Age-Group—An age-group of like physical property units is a group of units which were put into service during the same year.

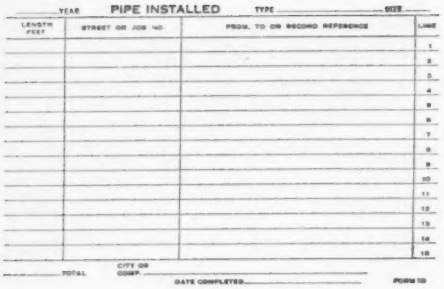
Mortality Survival Ratio—Mortality survival ratio is the proportion of survivors of the original members of large age-groups of like units from year to year during the period of the study, to the total, in the age group. The proportion is here expressed in percentage.

Mortality Survival Curves—Mortality survival curves are curves constructed from the mortality survival ratios of the actual service of the members of a group of like physical property units.

In computing mortality survival ratios physical property units were considered placed in service during a calendar year. Retirements of such units were considered made at the end of calendar years. If a unit was installed and retired in the first year of its life it was considered to have a service life of 0.5 of a year; if it was retired in the second year it was considered to have a service life of 1.5 years, etc.

The committee, in developing the information on which this series of reports is based, provided each co-operating utility with the forms to be used in making the reports. Reproductions of the forms follow on pages 650–653.

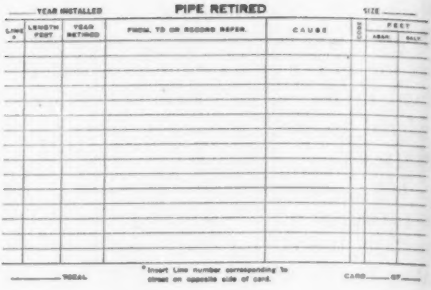
During the course of the committee's work it developed a method of expressing graphically the rate of retirement of the various types and sizes of water works structures. The data include such a number of years that the reproduction of the graphs within a JOURNAL page is very difficult. A single specimen graph appears facing page 650. Data in this graph are derived from the table on 4-in. Cast-Iron Unlined Mains, to appear with the Denver, Colo., report in the August JOURNAL.



YEAR **PIPE INSTALLED** TYPE SIZE

LENGTH FEET	STREET OR JOB NO	FROM, TO OR RECORD REFERENCE	LINE
			1
			2
			3
			4
			5
			6
			7
			8
			9
			10
			11
			12
			13
			14
			15

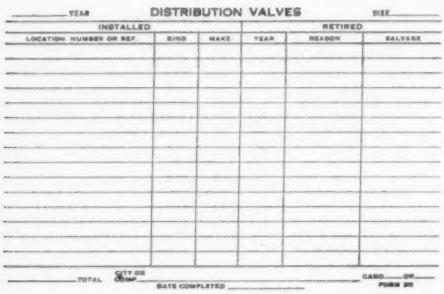
TOTAL CITY OR COMP. DATE COMPLETED FORM 10



YEAR INSTALLED **PIPE RETIRED** SIZE

LINE*	LENGTH FEET	YEAR RETIRED	FROM, TO OR RECORD REFER.	CAUSE	CODE	FEET ABAN.	FEET SALV.

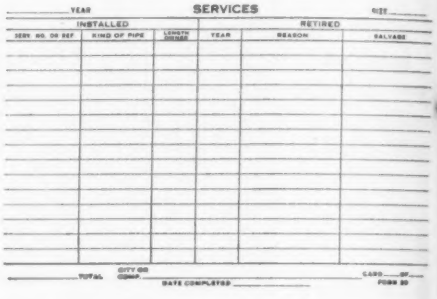
TOTAL *Insert Line number corresponding to street on opposite side of card. CARD OF



YEAR **DISTRIBUTION VALVES** SIZE

INSTALLED			RETIRED		
LOCATION NUMBER OR REF.	KIND	MAKE	YEAR	REASON	SALVAGE

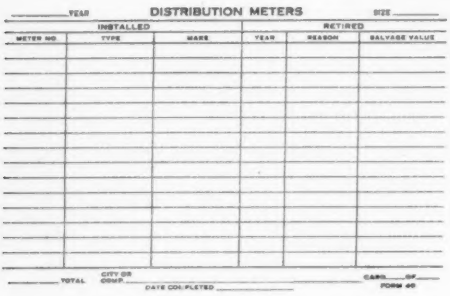
TOTAL CITY OR COMP. DATE COMPLETED CARD OF FORM 20



YEAR **SERVICES** SIZE

INSTALLED			RETIRED		
SERV. NO. OR REF	KIND OF PIPE	LENGTH FEET	YEAR	REASON	SALVAGE

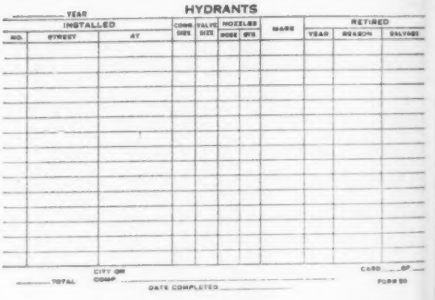
TOTAL CITY OR COMP. DATE COMPLETED CARD OF FORM 30



YEAR **DISTRIBUTION METERS** SIZE

INSTALLED			RETIRED		
METER NO.	TYPE	MAKE	YEAR	REASON	SALVAGE VALUE

TOTAL CITY OR COMP. DATE COMPLETED CARD OF FORM 40

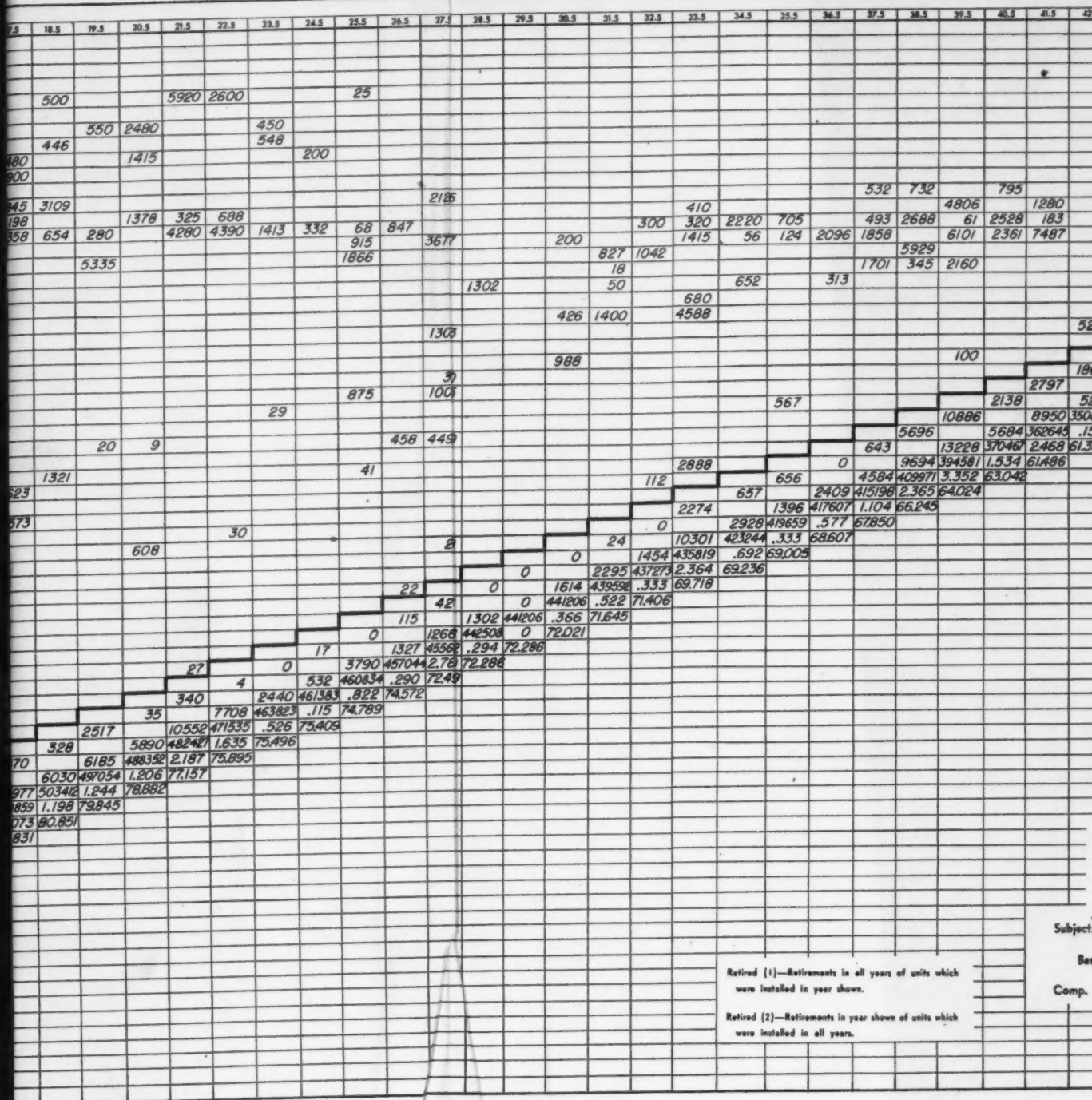


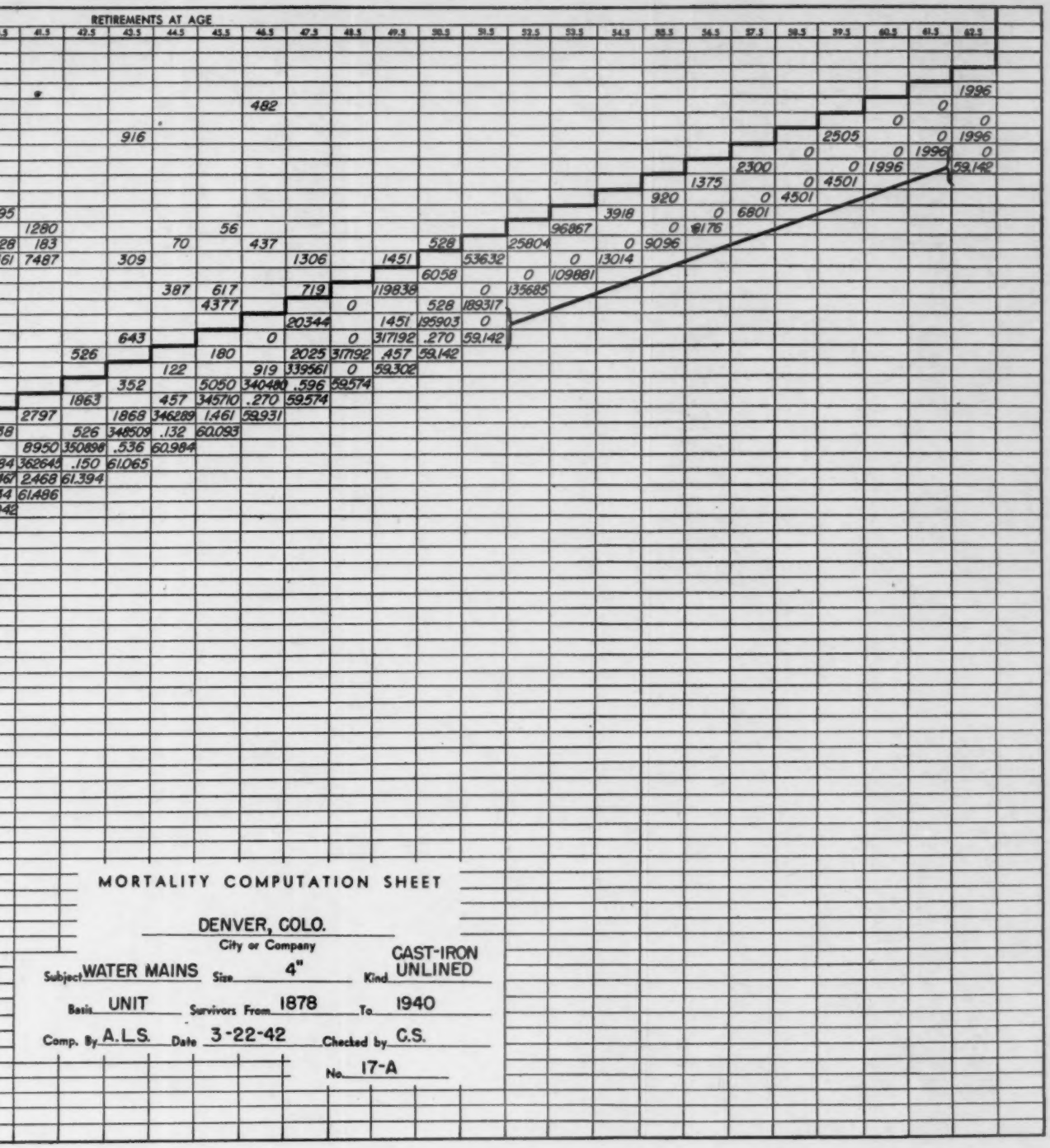
YEAR **HYDRANTS**

INSTALLED			CONN. DIES	VALVE SIZE	NOZZLES DIAM	NOZZLES QTY	MAKE	RETIRED		
NO.	STREET	AT						YEAR	REASON	SALVAGE

TOTAL CITY OR COMP. DATE COMPLETED CARD OF FORM 50

YEAR INSTAL.	FEET OR NUMBER				RETIREMENTS AT AGE															
	Installed	In Service	Retired (1)	Retired (2)	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5
1878	1,996	1,996																					
1879																							
1880														80	244								500
1881	12,356	-2,505	9,851																				
1882													81										
1883	6,777	2,300	4,477																				446
1884	2,369	1,375	994								135				773							480	
1885	3,923	920	3,003						48	95				1124						500	500	6900	
1886	13,085	3,918	9,167																				
1887	96,867	96,867																					
1888	76,032	25,804	50,228				1902	767				1634	1832		3078	12234	2905	6269	4441	7027		845	3109
1889	72,510	53,632	18,878			150					863				1080	440	1660	2074	2905		565	198	
1890	44,034	6,058	37,976	2,180						950	260		346		290	6880	998		1097			4358	654
1891	149,194	119,838	29,356	1,322																			
1892	33,793		33,793					1672			920			1800	400		4912	3900	799	4391			
1893	26,637	20,344	6,293				346																
1894	6,694		6,694											220									
1895	1,080	180	900	7,362												655							
1896	7,834	122	7,712	2,092																			
1897	2,181	352	1,829																				
1898	1,863	1,863		4,344								3915						985					
1899	8,685	2,797	5,888	13,814																			
1900	2,168	2,138	30	3,635												424							
1901	13,190	10,886	2,304	17,109															1285				
1902	7,577	5,696	1,881	15,809																			
1903	643	643		21,912																			
1904	4,986		4,986	6,229																			
1905	656	656		6,725																			1321
1906	5,572	657	4,915	8,496											665							623	
1907	3,009	2,274	735	9,952																			
1908				654																		2573	
1909	2,597	24	2,573	1,858																			
1910	553		553	325							523												
1911	2,721		2,721	10,303														2063	22				
1912				5,699																			
1913	426	426		1,413																			
1914	137	115	22	332																			
1915	36		36	2,194												36				36			
1916	53	17	36	4,235												27							
1917	27		27	1,866																			
1918	4	4		3,677																			
1919	367	340	27																				
1920	35	35																					
1921	2,517	2,517		200																			
1922	328	328		2,012																			
1923	470	470		1,167																			328
1924	422	422		10,014																		470	
1925	52	52		1,394																	422		6030
1926	943	943		5,682											179					52		15977	503412
1927	258	79	179	4,501															943		1065	519859	1.198
1928	979	979		12,511														79		11954	521346	3.073	80.851
1929	231	231		5,637													979		10549	533352	.204	81.831	
1930	256	256		18,310												231		15191	544844	2.241	84.425		
1931	64	64		8,073											256		10475	560114	1.936	84.598			
1932	9	9		9,677										64		20696	571568	2.712	86.537				
1933													9		6709	592495	1.833	88.245					
1934	177	177		435								0		3224	599460	3.493	90.705						
1935											177		2259	602748	1.119	92.399							
1936	62	62		437						0		5549	605016	.535	95.743								
1937	117	117		1,133					62		2701	610565	.373	96.826									
1938	67	67		2,051				117		1045	613443	.909	97.347										
1939				8,546			67		48	614488	.440	97.711											
1940	92	92		2,747																			
TOTALS	619,711	371,647	248,064	248,064		0		2439	614598	.170	98.607												
IN SERVICE BY AGE DISTR.					92		2248	617154	.008	99.043													
						150	619469	.395	99.212														
RETIREMENTS — UNITS					0	619619	.363	99.220															
EXPOSURES — UNITS					619711	.024	99.613																
RETIREMENT RATIO — %					0	99.976																	
SURVIVAL RATIO — %					100																		


Retired (1)—Retirements in all years of units which were installed in year shown.
Retired (2)—Retirements in year shown of units which were installed in all years.



MORTALITY COMPUTATION SHEET

DENVER, COLO.
City or Company

Subject WATER MAINS Size 4" Kind CAST-IRON UNLINED

Basis UNIT Survivors From 1878 To 1940

Comp. By A.L.S. Date 3-22-42 Checked by C.S.

No. 17-A

UNIV. OF MICH.

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FORM 100

CITY OR COMPANY

DATE .....

SUMMARY OF INSTALLATIONS AND RETIREMENTS

SUBJECT ..... SIZE ..... KIND ..... SHEET ..... OF .....

YEAR INSTAL.	FEET OR NUMBER			RETIREMENTS IN YEAR									
	Installed	In Service	Retired	1942	1941	1940	1939	1938	1937	1936	1935	1934	1933
1942													
1941													
1940													
1939													
1938													
1937													
1936													
...													
1890													
1889													
1888													
1887													
1886													
Carry													

FORM 100A

CITY OR COMPANY

DATE .....

SUMMARY OF INSTALLATIONS AND RETIREMENTS

SUBJECT ..... SIZE ..... KIND ..... SHEET ..... OF .....

YEAR INSTAL.	FEET OR NUMBER			RETIREMENTS IN YEAR									
	Installed	In Service	Retired	1942	1941	1940	1939	1938	1937	1936	1935	1934	1933
Brought													
Sub-Tot.													
Unknown													
Total													

FORM 100B

CITY OR COMPANY

DATE .....

SUMMARY OF INSTALLATIONS AND RETIREMENTS (Cont'd)

SUBJECT ..... SIZE ..... KIND ..... SHEET ..... OF .....

YEAR INSTAL.	RETIREMENTS IN YEAR												

IMPOUNDING RESERVOIRS

DATE
CITY OR COMP. SHEET OF

DESCRIPTION	NAME OR DESIGNATION KNOWN BY					
CAPACITY IN MILLION GALLONS						
STREAM IMPOUNDED						
CONTRIBUTORY DRAINAGE AREA, SQ. MI.						
SAFE YIELD OF SUPPLY, M.G.D.						
LENGTH OF DAM IN FEET						
WIDTH OF DAM IN FEET TOP / BOTTOM						
MAXIMUM HEIGHT OF DAM IN FEET						
MATERIALS OF CONSTRUCTION						
DETAILS OF CONSTRUCTION						
DETAILS OF RECONSTRUCTION, IF ANY						
DATE OF CONSTRUCTION, YEAR						
DATE OF RETIREMENT, YEAR						
REASON FOR RETIREMENT						
SALVAGE VALUE, IF ANY						
Do these include all Impounding Dams in your system since beginning of its history?						
If not, explain						

TUNNELS AND AQUEDUCTS

DATE
CITY OR COMP. SHEET OF

DESCRIPTION	NAME OR DESIGNATION KNOWN BY					
LENGTH IN FEET						
DIAMETER OR SIZE IN FEET						
MATERIALS OF CONSTRUCTION						
PURPOSE OF FACILITY						
DETAILS OF CONSTRUCTION						
DETAILS OF RECONSTRUCTION, IF ANY						
DATE OF CONSTRUCTION, YEAR						
DATE OF RETIREMENT, YEAR						
REASON FOR RETIREMENT						
SALVAGE VALUE, IF ANY						
Do these include all Tunnels & Aqueducts in your system since beginning of its history?						
If not, explain						

WELLS

DATE
CITY OR COMP. SHEET OF

DESCRIPTION	NAME OR DESIGNATION KNOWN BY					
TYPE OF WELL						
DIAMETER OR DIMENSIONS						
DEPTH IN FEET CASED / UNCASED						
KIND OF CASING						
CHARACTER OF SOIL						
STRAINER TYPE AND SIZE						
PUMPING DONE BY						
CAPACITY OF WELL OR PUMP						
DETAILS OF CONSTRUCTION						
DETAILS OF RECONSTRUCTION, IF ANY						
DATE OF CONSTRUCTION, YEAR						
DATE OF RETIREMENT, YEAR						
REASON FOR RETIREMENT						
SALVAGE VALUE, IF ANY						
Do these include all Wells in your system since beginning of its history?						
If not, explain						

INFILTRATION GALLERIES

DATE
CITY OR COMP. SHEET OF

DESCRIPTION	NAME OR DESIGNATION KNOWN BY					
TYPE OF GALLERY						
LENGTH IN FEET						
CROSS SECTION DIMENSIONS						
SOIL CHARACTER						
KIND OF LINING						
DETAILS OF CONSTRUCTION						
DETAILS OF RECONSTRUCTION, IF ANY						
DATE OF CONSTRUCTION, YEAR						
DATE OF RETIREMENT, YEAR						
REASON FOR RETIREMENT						
SALVAGE VALUE, IF ANY						
Do these include all Galleries in your system since beginning of its history?						
If not, explain						

PURIFICATION PLANTS

DATE
CITY OR COMP. SHEET OF

DESCRIPTION	NAME OR DESIGNATION KNOWN BY					

PUMPING EQUIPMENT

DATE
CITY OR COMP. SHEET OF

DESCRIPTION	NAME OR DESIGNATION KNOWN BY					

DESCRIPTION						
SALVAGE VALUE, IF ANY						
Do these include all Wells in your system since beginning of its history?						
If not, explain						

PURIFICATION PLANTS

CITY OR COMP. DATE

NAME OR DESIGNATION KNOWN BY SHEET OF

DESCRIPTION						
NOMINAL SIZE M.G.D.						
AERATOR DESCRIPTION						
MIXING BASIN NO. OF UNITS SIZE OF UNITS						
COAGULATING BASIN NO. OF UNITS SIZE OF UNITS						
FILTER UNITS NO. OF UNITS SIZE OF UNITS						
CLEAR WELL CAPACITY						
DESCRIPTION OF PLANT, ETC.						
DETAILS OF CONSTRUCTION						
DETAILS OF RECONSTRUCTION, IF ANY						
DATE OF CONSTRUCTION, YEAR						
DATE OF RETIREMENT, YEAR						
REASON FOR RETIREMENT						
SALVAGE VALUE, IF ANY						
Do these include all Purification Plants in your system since beginning of its history?						
If not explain						

DISTRIBUTION RESERVOIRS

CITY OR COMP. DATE

NAME OR DESIGNATION KNOWN BY SHEET OF

DESCRIPTION						
CAPACITY IN MILLION GALLONS						
LENGTH IN FEET						
WIDTH IN FEET						
AVERAGE DEPTH IN FEET						
MATERIALS OF CONSTRUCTION						
COVERED OR UNCOVERED						
DETAILS OF CONSTRUCTION						
DETAILS OF RECONSTRUCTION, IF ANY						
DATE OF CONSTRUCTION, YEAR						
DATE OF RETIREMENT, YEAR						
REASON FOR RETIREMENT						
SALVAGE VALUE, IF ANY						
Do these include all distribution reservoirs, standpipes or Tanks and Standpipes in your system since beginning of its history?						
If not, explain						

PUMPING EQUIPMENT

CITY OR COMP. DATE

NAME OR DESIGNATION KNOWN BY SHEET OF

DESCRIPTION						
CAPACITY OF UNIT IN M.G.D.						
TYPE OF UNIT						
PUMPING HEAD IN FEET						
PRIME MOVER						
HORSEPOWER OF PRIME MOVER						
DESCRIPTION OF UNIT						
CONDITIONS OF OPERATION						
INDICATED EFFICIENCY						
DATE OF INSTALLATION, YEAR						
DATE OF RETIREMENT, YEAR						
REASON FOR RETIREMENT						
SALVAGE VALUE, IF ANY						
Do these include all Pumping Equipment in your system since beginning of its history?						
If not explain						

ELEVATED TANKS AND STANDPIPES

CITY OR COMP. DATE

NAME OR DESIGNATION KNOWN BY SHEET OF

DESCRIPTION						
STANDPIPE OR ELEVATED TANK						
MATERIALS OF CONSTRUCTION						
CAPACITY IN GALLONS						
DIAMETER IN FEET						
CAPACITY DEPTH IN FEET						
HEIGHT TO FLOW LINE, IN FEET						
TYPE OF TANK BOTTOM TOP						
COVERED OR UNCOVERED						
YEARS BETWEEN PAINTINGS INSIDE OUTSIDE						
ERECTED BY						
DATE OF ERECTION, YEAR						
DATE OF RETIREMENT, YEAR						
REASON FOR RETIREMENT						
SALVAGE VALUE, IF ANY						
Do these include all standpipes and tanks in your system since beginning of its history?						
If not explain						

Ottawa, Ontario—Survival and Retirement Experience With Water Works Facilities

As of December 31, 1940

THE Ottawa Water Works system is a municipal plant serving the city of Ottawa in the Province of Ontario, Canada; the adjacent municipalities of Eastview and Rockcliffe; and portions of Nepean and Gloucester Townships.

Ottawa is chiefly important as the capital city of the Dominion. Within the city there were, as of the date of the study, 30,234 consumers and in the adjacent communities 2,224, or a total of 32,458 consumers, corresponding to an estimated population of about 165,116 served by the system. Consumption averaged 18.5 mgd. (Imp.) in 1940, or about 111.8 gpd. per capita. (Imperial gallons are used throughout this report. One gallon (Imp.) is equal to 1.201 gal. (U.S.).)

Industrial activity is not prominent in Ottawa. The Parliament buildings are located there and it is the center of many governmental agencies, which are reflected by a high type of residential development within and adjacent to the city.

Development of the Existing System

The Ottawa Water Works was founded in the year 1872, as a result of negotiations carried on by the Corporation and the Dominion Government from 1869 to 1872. In 1872 certain rights to use water from the Ottawa River for water supply and power purposes were granted by the Dominion Government.

Construction of the original Queen Street Pumping Station, Aqueduct No. 1 and the distribution system was started in 1873. The supply has always been secured from the Ottawa River, which provides an abundant and excellent source of soft water. Until 1913 all pumping was done by hydraulic power and more than 25 per cent of the high-lift pumping is still done by water power.

In the period of original construction, 1873–1876, the Queen Street Pumping Station, including pumping unit Nos. 1, 2 and 3; Aqueduct No. 1; and a 30-in. wood stave supply line were built. In 1890 the wood stave line was replaced by a 40-in. steel pipeline and extended to near Lemieux Island, 2 mi. upstream; the Queen Street Station was enlarged and No. 4 pumping unit installed. Further extensions were made in 1899–1900 to house pumping unit Nos. 5, 6, 7 and 8.

During the period 1907–1912, Aqueduct No. 2 and a new 42-in. steel pipe supply line were built. In 1913, electric low-lift pumping was started in a station constructed at Lemieux Island. Also in this year additional fire pressure, utilized only when necessary, was provided in the congested business area. Several additions to the pumping and transmission works were constructed in 1915, 1916, 1917 and 1922.

In 1929–1932, the Lemieux Island Purification Plant was constructed to

TABLE 1

SUMMARY OF MAINS

OTTAWA, ONTARIO

Size, *in.*	Kind	No. of Feet Installed	Percentage of Total	No. of Feet Retired	Percentage of Total	No. of Feet in Service	Percentage of Total	Year of First Installation	Average Age, *yr.*
51	Steel	18,890	1.66	0	0.00	18,890	1.75	1918	21.7
48	Concrete	2,433	0.21	0	0.00	2,433	0.22	1937	3.5
42	Steel	5,450	0.48	3,050	5.22	2,400	0.22	1912	28.5
40	Steel	6,006	0.53	0	0.00	6,006	0.56	1890	50.5
36		6,853	0.61	0	0.00	6,853	0.63	1916	24.3
30		2,046	0.18	0	0.00	2,046	0.19	1916	24.2
24		12,747	1.12	0	0.00	12,747	1.18	1890	30.2
20		5,235	0.46	0	0.00	5,235	0.48	1916	20.2
18		8,924	0.78	0	0.00	8,924	0.83	1915	24.8
16		37,166	3.26	0	0.00	37,166	3.44	1912	15.3
15	Cast-iron	30,476	2.67	144	0.25	30,332	2.80	1874	52.6
12	unlined	80,221	7.04	550	0.94	79,671	7.37	1874	35.8
10		10,865	0.95	0	0.00	10,865	1.00	1908	27.5
8		126,102	11.06	560	0.96	125,542	11.61	1874	37.7
6		360,631	31.64	4,328	7.40	356,303	32.95	1875	25.3
5		337,292	29.59	27,831	47.58	309,461	28.62	1874	53.8
4		42,449	3.72	3,392	5.80	39,057	3.61	1884	38.4
3		46,075	4.04	18,628	31.85	27,447	2.54	1874	50.7
TOTAL		1,139,861	100.00	58,483	100.00	1,081,378	100.00		37.3
Percentage of Total		100.00		5.13		94.87			
Average Size, *in.*		8.53		6.42		8.64			

Mortality Survival Ratios

Size, *in.*	Kind	No. of Feet	Period Covered, *yr.*	Percentage
3–5		425,816	66.5	80.557
6		360,631	65.5	74.520
8	Cast-iron	126,102	66.5	98.220
10 and 12	unlined	91,086	66.5	99.081
Over 12		103,447	66.5	99.561
40–51	Steel	30,346	50.5	73.376
48	Concrete	2,433	3.5	100.000
TOTAL		1,139,861		

TABLE 2

SUMMARY OF METERS

OTTAWA, ONTARIO

Size, *in.*	Kind	Number Purchased	Number Sold or Returned to Factory	Number Installed	Number Retired	Number in Service	Average Age, *yr.*
⅜	Rotary	1	0	1	1	0	0
½		7	0	7	0	7	10.5
⅝		433	35	398	31	367	20.7
¾		151	15	136	3	133	18.0
1		58	3	55	0	55	19.1
1¼		3	1	2	0	2	8.5
1½		15	3	12	2	10	15.2
2		28	11	17	0	17	23.7
3		14	2	12	1	11	21.0
4		2	0	2	1	1	25.5
6		3	0	3	0	3	25.5
⅝	Disc	1,008	73	935	42	893	14.1
¾		539	138	401	9	392	12.2
1		324	39	285	16	269	16.7
1¼		18	4	14	1	13	17.8
1½		124	11	113	1	112	11.9
2		221	7	214	3	212	20.8
3		33	0	33	1	32	11.8
1½	Current	3	1	2	0	2	26.5
2		55	3	52	16	36	21.7
3		41	4	37	4	33	24.8
4		36	1	35	1	33	23.7
6		20	0	20	0	20	22.5
8		4	0	4	0	4	21.0
1½	Compound	1	0	1	0	1	21.5
2		25	0	25	0	25	19.7
3		31	0	31	0	31	19.0
4		22	0	22	0	22	18.4
6		28	4	24	0	24	17.7
8		17	7	10	0	10	16.2
TOTAL		3,265	362	2,903	133	2,770	17.6

Mortality Survival Ratios

Size, *in.*	Kind	Number	Period Covered, *yr.*	Percentage
⅝	Rotary	398	25.5	90.344
⅝	Disc	935	39.5	15.231
⅜–6 (excl. ⅝)	Rotary	247	25.5	94.352
¾–3	Disc	1,060	40.5	8.141
1½–8	Compound	113	25.5	100.000
1½–8	Current	150	31.5	30.016
TOTAL		2,903		

provide full purification treatment of the supply. This is a modern, rapid sand filtration plant of substantial and attractive construction, providing chemical storage and feeding, mixing, settling, filtration and chlorination and the necessary low- and high-lift pumping plants. There are ten filter units of 3.5-mgd. rated capacity each. When the purification plant was placed in service the under-water portion of the 42-in. steel main was no longer used and, although still in place, was considered retired as of that date.

The transmission system consists of approximately 5.6 mi. of 40- to 51-in. steel and concrete pipelines from the Lemieux Island plant to the distribution system and to the Queen Street Pumping Station. There are in the distribution system approximately 200 mi. of cast-iron mains from 3 to 36 in. in diameter. The greater portion of the system consists of pit-cast, bell-and-spigot, Class C pipe. Formerly the pipe was laid with a 5-ft. minimum cover. Due to the routine of snow removal, freezing became a problem and mains are now generally laid with a 6.5-ft. cover.

There are approximately 30,000 services within the city, which, with the exception of the larger cast-iron services, are of lead. The system has 2,525 valves, 1,618 hydrants and 2,326 meters. With the exception of the larger buildings, commercial and manufacturing establishments, schools and government buildings, the domestic services are unmetered. Approximately 34.7 per cent of the total amount of water pumped in 1940 was used through service meters.

Basis of Study

The records of the system pertaining to distribution and transmission mains, services, meters and Class B facilities are complete from the date of construction or installation, beginning in 1872. Annual reports are available from 1874 to the present date, and the additions to the system and the retirements therefrom are stated to be complete.

The work of abstracting the records of installation and retirement of mains and meters and the compiling of the data into the form prescribed for the use of the Committee on Survival and Retirement Experience With Water Works Facilities, was carried out by the regular staff of the department. While the records of service installations and retirements are complete, the immense amount of work required for abstracting and compiling the information required was beyond the ability of the existing force to do in the circumstances prevailing at the time the study was being made.

Mortality Survival Study

From the compilation of additions and retirements a mortality study was made of the transmission and distribution mains and meters. Table 1 is a summary of all of the pipe installed and retired as well as data relating to average ages, length of record, mortality survival ratio and average sizes. Figure 1 shows the mortality survival curves covering the entire record of the sizes of pipe shown.

Table 2 is a similar summary for meters and Fig. 2 shows the corresponding mortality survival curves. The department records include all meters which have been purchased and put into service. Many of the smaller meters were located on services outside the city limits. Upon investigation it was found that a substantial portion of these meters was sold to

TABLE 3

CAUSES OF RETIREMENTS OF MAINS

OTTAWA, ONTARIO

Size in.	Kind	Length ft.	Life yr.	Cause of Retirement
42	Steel	3,050	20.5	Under-water crossing, not used after filter plant went into operation
15	Cast-iron	144	25.5	Civic center improvement
12	Cast-iron	550	28.5	Superseded by construction of 48-in. concrete line
8	Cast-iron	60	46.5	Frost fracture
		500	41.5	Bolted under-water crossing, bolt corrosion
6	Cast-iron	384	47.5	
		192	45.5	
		636	39.5	
		540	34.5	Frost fracture
		475	29.5	
		380	21.5	
		1,100	20.5	
		300	58.5	Leakage, under 30-ft. fill
		200	41.5	Civic center improvement
		121	12.5	Inadequate
5	Cast-iron	176	48.5	
		64	44.5	
		76	43.5	
		228	37.5	
		300	34.5	
		75	33.5	Frost fracture
		1,200	28.5	
		104	27.5	
		401	23.5	
		803	21.5	
		1,100	62.5	Street elimination
5	Cast-iron	1,050	59.5	Street elimination
		250	34.5	Physical
		1,405	64.5	
		5,040	59.5	
		814	58.5	
		260	56.5	
		1,350	53.5	
		564	45.5	
		608	44.5	
		3,209	36.5	Inadequate
		500	35.5	
		480	34.5	
		1,780	31.5	
		1,500	29.5	
		516	25.5	
		2,466	19.5	
		800	14.5	
		550	65.5	
		126	30.5	Unknown
		36	29.5	
4	Cast-iron	416	40.5	
		160	39.5	Frost fracture
		256	16.5	
		697	21.5	
		200	15.5	
		400	13.5	Inadequate
		639	10.5	
		624	8.5	
3	Cast-iron	129	37.5	Frost fracture
		2,700	58.5	
		499	41.5	
		1,291	36.5	
		2,871	35.5	
		2,629	34.5	Inadequate
		2,513	20.5	
		1,752	19.5	
		1,062	13.5	
		1,486	56.5	
		475	55.5	
		700	34.5	Unknown
		521	22.5	

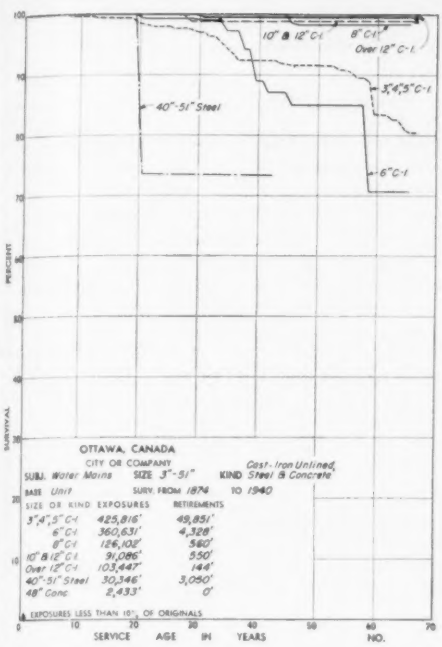
10" & 12" C-1
8" C-1
Over 12" C-1
3",4",5" C-1
40"-51" Steel
6" C-1
OTTAWA, CANADA
CITY OR COMPANY
SUBJ. Water Mains SIZE 3"-51" KIND Cast-Iron Unlined, Steel & Concrete
BASE Unit SURV. FROM 1874 TO 1940
SIZE OR KIND EXPOSURES RETIREMENTS
3",4",5" C-1 425,816' 49,851'
6" C-1 360,631' 4,328'
8" C-1 126,102' 560'
10" & 12" C-1 91,086' 550'
Over 12" C-1 103,447' 144'
40"-51" Steel 30,346' 3,050'
48" Conc 2,493' 0'
EXPOSURES LESS THAN 10% OF ORIGINALS
PERCENT SURVIVAL
SERVICE AGE IN YEARS
NO.

FIGURE 1

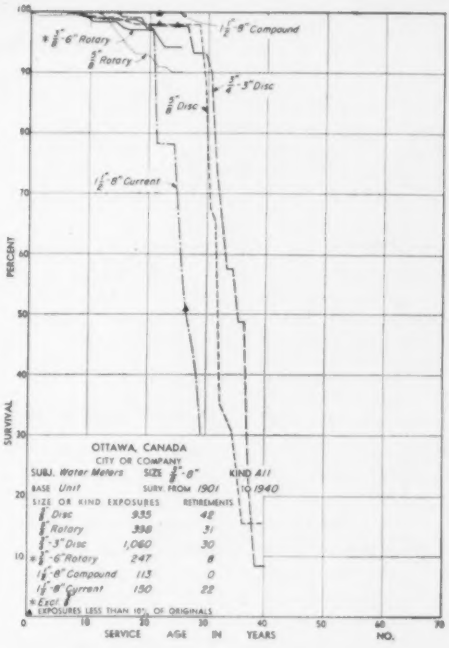

FIGURE 2

the consumer after installation. Generally it is stated that these meters are still in service, but the department has no record available as to what happens to them after their sale. These meters were, therefore, omitted from the installations in computing the mortality survival curves.

A summary of the basic data covering installations and retirements is appended hereto.

Causes of Retirements

The records of the department contain substantially all the reasons why mains and meters were retired. Table 3 gives a summary by sizes of the causes of retirements of mains. Of the total retirements of water mains, approximately 72.4 per cent were caused by inadequacy, 5.2 per cent were ordered by public authorities, 13.9 per cent resulted from freezing and 8.5 per cent were caused by other factors, including 6.7 per cent which could not be definitely determined from the records.

Tuberculation and corrosion are not serious problems with the mains in Ottawa. Inadequacy has been the main cause of retirements since the early system contained a preponderant part of 3-, 4- and 5-in. pipe which have had to be replaced with larger sizes. Snow removal, resulting in deeper penetration of frost, has caused considerable trouble from freezing and breaking in the older pipe, which had less cover than is now being provided.

The causes of the retirements of meters are shown in Table 4. As may be noted, 88 per cent were caused by physical wear and tear, 7 per cent were stolen and approximately 5 per cent

TABLE 4

CAUSES OF RETIREMENTS OF METERS
OTTAWA, ONTARIO

Size in.	Kind	Number	Life yr.	Cause of Retirement	Size in.	Kind	Number	Life yr.	Cause of Retirement
⅜	Rotary	1	22.5	Frozen	¾	Disc	1	35.5	Stolen
							1	8.5	Stolen
⅝	Rotary	3	21.5				1	37.5	
		1	13.5	Stolen			1	35.5	
		1	11.5				2	33.5	Wear and tear
		1	21.5				1	30.5	
		3	20.5				2	13.5	
		3	17.5						
		4	16.5		1	Disc	2	38.5	
		5	15.5	Wear and tear			2	37.5	
		4	14.5				1	33.5	
		4	13.5				2	32.5	
		1	8.5				3	31.5	Wear and tear
		1	7.5				2	27.5	
							1	18.5	
¾	Rotary	1	16.5	Stolen			1	17.5	
		1	9.5	Lost in fire			1	14.5	
		1	23.5	Wear and tear			1	12.5	
1½	Rotary	2	5.5	Wear and tear	1¼	Disc	1	14.5	Wear and tear
3	Rotary	1	10.5	Wear and tear	1½	Disc	1	19.5	Wear and tear
4	Rotary	1	10.5	Wear and tear	2	Disc	1	31.5	Wear and tear
							1	9.5	Frozen
⅝	Disc	1	15.5	Stolen			1	6.5	Frozen
		1	18.5	Frozen					
		1	13.5	Frozen	3	Disc	1	7.5	Frozen
		3	37.5						
		2	36.5		2	Current	2	26.5	
		1	35.5				2	25.5	
		1	34.5				11	21.5	Wear and tear
		13	33.5				1	19.5	
		1	32.5	Wear and tear					
		9	31.5		3	Current	1	28.5	
		4	30.5				1	27.5	Wear and tear
		1	17.5				2	25.5	
		1	16.5						
		3	13.5		4	Current	1	29.5	Wear and tear

were retired because of freezing and the damage caused thereby.

Acknowledgments

The collection and compilation of data in Ottawa were under the general supervision of W. E. MacDonald, City Water Works Engineer and a member of the Committee on Survival and Retirement Experience With Water Works Facilities. Assisting him in this work were C. D. Wight, H. P. Stockwell, C. T. Heeney, H. R. Hooper, W. A. Featherston and personnel under their direction.

Summary of Class B Facilities
Ottawa, Ontario

Purification Plant

Lemieux Island rapid sand filtration plant, rated 35-mgd. capacity, consisting of three spiral flow mixing chambers, three coagulating basins, ten 3.5-mgd. filter units, with clear well capacity of 6 mil.gal. Plant has low- and high-lift pumping stations. Constructed in 1932 of reinforced concrete with brick veneer and limestone trim and still in service.

Pumping Stations

Lemieux Island high- and low-lift pumping stations are an integral part of the filtration plant.

Queen Street Pumping Station, where high-lift pumping is partially done, largely by water power, is the original station, constructed of stone masonry in 1873–1874. Several additions have been made since the original station was built.

Pumping Equipment

Lemieux Island—Low-Lift

Unit Nos. 1, 2 and 3—17.5-mgd. horizontal, centrifugal pumping units; 47.5-ft. head; driven by 200-hp. squirrel cage motors. Installed in 1932 (motors purchased in 1922); still in service.

Unit No. 4—35-mgd. horizontal centrifugal pumping unit; 47.5-ft. head; driven by 420-hp. diesel oil engine. Installed in 1932; still in service.

Lemieux Island—High-Lift

Unit Nos. 1 and 2—20-mgd. horizontal, double-stage centrifugal pumping units; 280-ft. head; driven by 1,600-hp. wound rotor induction motors. Installed in 1917; still in service.

Unit Nos. 3 and 4—17-mgd. horizontal, single-stage centrifugal pumping units; 210-ft. head; driven by 950-hp. synchronous motors. Installed in 1932 and 1934; still in service.

Wash water pumps, Nos. 1 and 2—5-mgd. horizontal, centrifugal pumping units; 40-ft. head; driven by 60-hp. squirrel cage motors. Installed in 1932; still in service.

Lemieux Island—River Low-Lift

Unit Nos. 1, 2, 3 and 4—12-mgd. roturbo units; 18-ft. head; belt driven by electric motors installed in 1913 to provide head on submarine pipeline because of typhoid epidemic. Very inefficient and units were retired in 1915 and placed in storage. Replaced by four horizontal, centrifugal pumping units; 18-ft. head; driven by 85-hp. squirrel cage motors. Installed: one in 1913, three in 1915; one retired in 1932 and three in 1940. Units held in storage.

Queen Street Pumping Station

Unit Nos. 1, 2 and 3—3-mgd. reciprocating pumping units against 150-lb. pressure driven by hydraulic turbines. Installed in 1874; still in service, but face early retirement.

Unit No. 4—10-mgd. reciprocating pumping unit driven by hydraulic turbine. Installed in 1890; retired 1934 at scrap value.

New Unit No. 4—17-mgd. centrifugal pumping unit, 210-ft. head, driven by 760-hp. hydraulic turbine. Installed in 1935; still in service.

Unit Nos. 5, 6, 7 and 8—8-mgd. reciprocating pumping units, double duplex; 110-lb. head; driven by 1,400-hp. hydraulic turbines. Installed in 1900 and 1908; still in service.

Unit Nos. 9 and 9a—12-mgd. centrifugal pumping units, two single stage; usable alone or in series; 225- to 270-ft. head; driven by 750- and 160-hp. wound rotor induction motors. Installed in 1915; still in service.

Slater Street Booster Station

Unit No. 1—2,000-gpm. roturbo-type pumping unit; 80-lb. head; driven by 165-hp. induction motor. Installed in 1913; retired 1940 due to fracture of pump casing, at scrap value.

New Unit No. 1—2,000-gpm. centrifugal pumping unit; 80-lb. head; driven by 150-hp. induction motor. Installed in 1940; still in service.

Unit No. 2—2,000-gpm. roturbo-type pumping unit; 80-lb. head; driven by 165-hp. induction motor. Installed in 1913; still in service.

Unit No. 3—2,000-gpm. roturbo-type pumping unit; 80-lb. head; driven by 175-hp. induction motor. Installed in 1916; still in service.

Summary of Installations and Retirements
Ottawa, Ontario

Mains

3-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1874	7,485	4,060	3,425
1875	8,994	600	8,394
1876	3,560	1,270	2,290
1877	2,465	1,460	1,005
1878	286	286	0
1880	63	63	0
1882	240	240	0
1883	150	150	0
1884	50	50	0
1885	1,425	1,425	0
1886	1,486	1,486	0
1887	7,743	6,339	1,404
1889	1,569	1,221	348
1890	620	620	0
1895	1,053	1,053	0
1896	1,100	400	700
1897	1,127	65	1,062
1899	925	925	0
1904	336	336	0
1905	160	160	0
1908	613	613	0
1909	1,454	1,454	0
1910	985	985	0
1911	198	198	0
1912	260	260	0
1913	120	120	0
1914	252	252	0
1920	402	402	0
1921	216	216	0
1924	440	440	0
1925	298	298	0
1940	0	0	0
Total	46,075	27,447	18,628

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1874	521	1896	204	1915	2,700	1933
1875	2,513	1908	2,627	1909	1,291	1911
	475	1930	1,488	1931		
1876	1,995	1911	295	1917		
1877	876	1912	129	1914		
1887	401	1906	1,003	1907		
1889	348	1907				
1896	700	1930				
1897	1,062	1910				

4-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1884	535	535	0
1885	375	375	0
1886	697	0	697
1889	3,073	3,073	0
1891	1,502	1,502	0
1892	766	766	0
1893	1,940	1,476	464
1894	1,187	1,187	0
1895	3,555	2,779	776
1896	4,425	3,786	639
1897	2,195	2,195	0
1899	633	633	0
1900	280	280	0
1901	680	680	0
1902	644	644	0
1904	192	192	0
1907	1,032	1,032	0
1908	12,508	11,884	624
1909	550	550	0
1910	1,230	1,230	0
1911	752	752	0
1913	266	266	0
1916	600	600	0
1920	1,040	848	192
1921	228	228	0
1923	312	312	0
1928	508	508	0
1929	360	360	0
1939	100	100	0
1940	284	284	0
Total	42,449	39,057	3,392

4-IN. CAST-IRON UNLINED MAINS.-(contd.)

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year	Year Installed	Feet	Year	Feet	Year	Feet	Year
1886	697	1907					1896	639	1908				
1893	400	1909	64	1936			1908	624	1916				
1895	200	1910	160	1934	416	1935	1920	192	1936				

5-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet			Year Installed	Feet		
	Installed	In Service	Retired		Installed	In Service	Retired
1874	65,852	50,374	15,478	1897	9,901	9,901	0
1875	18,290	15,660	2,630	1898	5,711	5,711	0
1876	2,304	2,304	0	1899	6,228	6,000	228
1877	35,285	33,910	1,375	1900	1,414	1,414	0
1878	10,517	9,017	1,500	1901	3,251	3,251	0
1880	4,142	4,142	0	1902	2,860	2,860	0
1881	2,453	2,453	0	1903	5,311	5,311	0
1882	2,282	2,282	0	1904	1,983	1,983	0
1883	293	293	0	1905	456	456	0
1884	2,500	2,500	0	1906	3,047	3,047	0
1885	3,889	3,889	0	1907	2,996	1,176	1,820
1886	9,773	9,773	0	1908	7,470	6,508	962
1887	27,115	24,026	3,089	1909	1,441	1,441	0
1888	6,834	6,834	0	1910	1,836	1,836	0
1889	30,741	30,164	577	1911	477	477	0
1890	10,761	10,697	64	1912	252	252	0
1891	2,788	2,712	76	1913	128	96	32
1892	3,157	3,157	0	1914	1,140	1,140	0
1893	9,577	9,577	0	1918	440	440	0
1894	15,635	15,635	0	1930	700	700	0
1895	6,014	6,014	0	1940	0	0	0
1896	10,048	10,048	0				
				TOTAL	337,292	309,461	27,831

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year	Year Installed	Feet	Year	Feet	Year	Feet	Year
1874	1,780	1905	1,320	1906	3,209	1910	1889	401	1912	176	1936		
	260	1930	814	1932	5,040	1933	1890	64	1934				
	1,100	1936	1,405	1938	550	1939	1891	76	1934				
1875	780	1909	500	1910	1,350	1928	1899	228	1936				
1877	75	1910	250	1911	1,050	1936	1907	516	1932	104	1934	1,200	1935
1878	1,500	1907					1908	800	1922	36	1937	126	1938
1887	1,146	1906	771	1908	608	1931	1913	32	1934				
	564	1932											

6-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired	Year Installed	Feet Installed	Feet In Service	Feet Retired
1875	1,780	1,480	300	1917	2,276	2,276	0
1877	200	0	200	1918	285	285	0
1887	700	700	0	1919	6,283	6,283	0
1889	4,788	4,408	380	1920	11,358	11,358	0
1890	192	0	192	1921	15,323	15,323	0
1892	1,506	966	540	1922	17,492	17,492	0
1894	684	300	384	1923	13,259	13,259	0
1896	121	0	121	1924	4,837	4,837	0
1898	636	0	636	1925	1,498	1,498	0
1899	655	655	0	1926	2,250	2,250	0
1900	1,457	1,457	0	1927	4,191	4,191	0
1901	36	36	0	1928	2,426	2,426	0
1902	560	560	0	1929	494	494	0
1903	744	744	0	1930	7,466	7,466	0
1904	2,064	2,064	0	1931	3,079	3,079	0
1905	3,399	3,399	0	1932	2,886	2,886	0
1906	8,698	8,698	0	1933	2,208	2,208	0
1907	6,825	6,665	160	1934	2,924	2,924	0
1908	63,534	62,434	1,100	1935	6,518	6,518	0
1909	28,920	28,920	0	1936	6,002	6,002	0
1910	24,860	24,545	315	1937	3,520	3,520	0
1911	22,835	22,835	0	1938	2,289	2,289	0
1912	15,238	15,238	0	1939	3,984	3,984	0
1913	16,849	16,849	0	1940	3,493	3,493	0
1914	15,278	15,278	0				
1915	8,147	8,147	0	Total	360,631	356,303	4,328
1916	3,584	3,584	0				

Retirements by Years

Year Installed	Feet	Year	Year Installed	Feet	Year	Year Installed	Feet	Year
1875	300	1933	1892	540	1926	1907	160	1936
1877	200	1918	1894	384	1931	1908	1,100	1928
1889	380	1910	1896	121	1908	1910	315	1939
1890	192	1935	1898	636	1937			

8-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired	Year Installed	Feet Installed	Feet In Service	Feet Retired
1874	13,040	13,040	0	1895	912	912	0
1875	2,920	2,920	0	1896	8,941	8,941	0
1876	1,370	1,370	0	1897	6,134	6,134	0
1877	1,960	1,960	0	1899	2,060	2,060	0
1878	590	590	0	1902	45	45	0
1886	915	915	0	1903	6,500	6,500	0
1887	3,364	2,864	500	1904	4,314	4,314	0
1888	2,818	2,758	60	1906	1,528	1,528	0
1889	2,829	2,829	0	1907	2,392	2,392	0
1890	936	936	0	1908	23,348	23,348	0
1891	500	500	0	1909	6,156	6,156	0
1894	234	234	0	1910	4,957	4,957	0

8-IN. CAST-IRON UNLINED MAINS (contd.)

Year Installed	Feet Installed	Feet In Service	Feet Retired
1911	2,408	2,408	0
1912	3,003	3,003	0
1914	1,694	1,694	0
1915	816	816	0
1916	722	722	0
1917	256	256	0
1922	252	252	0
1923	3,150	3,150	0
1925	288	288	0
1926	800	800	0
1927	288	288	0
1928	540	540	0
1930	930	930	0
1931	1,006	1,006	0
1932	2,179	2,179	0
1933	2,826	2,826	0
1936	2,982	2,982	0
1938	996	996	0
1939	2,203	2,203	0
1940	0	0	0
TOTAL	126,102	125,542	560

Retirements by Years

Year Installed	Feet	Year
1887	500	1932
1888	60	1934

10-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1908	7,110	7,110	0
1915	1,289	1,289	0
1920	942	942	0
1922	40	40	0
1923	744	744	0
1938	740	740	0
1940	0	0	0
TOTAL	10,865	10,865	0

12-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1874	8,490	8,490	0
1875	4,850	4,850	0
1889	6,307	6,307	0
1890	1,974	1,974	0
1895	1,563	1,563	0
1896	521	521	0
1897	6,112	6,112	0
1903	1,792	1,792	0
1904	252	252	0
1906	4,211	4,211	0
1907	2,719	2,719	0
1908	3,560	3,010	550
1909	540	540	0
1910	6,213	6,213	0
1911	240	240	0
1912	3,370	3,370	0
1913	2,830	2,830	0
1915	6,696	6,696	0
1916	1,138	1,138	0
1919	900	900	0
1920	1,450	1,450	0
1921	2,472	2,472	0
1922	555	555	0
1926	800	800	0
1928	1,040	1,040	0
1931	1,488	1,488	0
1932	564	564	0
1933	1,944	1,944	0
1934	2,622	2,622	0
1939	3,008	3,008	0
1940	0	0	0
TOTAL	80,221	79,671	550

Retirements by Years

Year Installed	Feet	Year
1908	550	1936

15-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1874	5,460	5,460	0
1875	7,770	7,770	0
1888	4,248	4,248	0
1890	222	222	0
1895	2,394	2,394	0
1897	960	960	0
1898	2,351	2,351	0
1903	3,195	3,195	0
1905	1,780	1,780	0
1909	401	257	144
1911	770	770	0
1914	510	510	0
1916	380	380	0
1926	35	35	0
1940	0	0	0
Total	30,476	30,332	144

Retirements by Years

Year Installed	Feet	Year
1909	144	1939

16-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1912	2,502	2,502	0
1913	7,645	7,645	0
1914	552	552	0
1915	16,093	16,093	0
1916	6,738	6,738	0
1917	20	20	0
1931	3,416	3,416	0
1938	200	200	0
1940	0	0	0
Total	37,166	37,166	0

18-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1915	2,510	2,510	0
1916	6,414	6,414	0
1940	0	0	0
Total	8,924	8,924	0

20-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1916	3,843	3,843	0
1932	1,392	1,392	0
1940	0	0	0
Total	5,235	5,235	0

24-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1890	170	170	0
1906	2,874	2,874	0
1907	961	961	0
1912	8,402	8,402	0
1913	192	192	0
1916	4	4	0
1939	144	144	0
1940	0	0	0
Total	12,747	12,747	0

30-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1916	1,476	1,476	0
1917	570	570	0
1940	0	0	0
Total	2,046	2,046	0

36-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1916	5,741	5,741	0
1917	1,112	1,112	0
1940	0	0	0
Total	6,853	6,853	0

40-IN. STEEL MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1890	6,006	6,006	0
1940	0	0	0
TOTAL	6,006	6,006	0

42-IN. STEEL MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1912	5,450	2,400	3,050
1940	0	0	0
TOTAL	5,450	2,400	3,050

Retirements by Years

Year Installed	Feet	Year
1912	3,050	1932

48-IN. STEEL CONCRETE-LINED AND COATED MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1937	2,433	2,433	0
1940	0	0	0
TOTAL	2,433	2,433	0

51-IN. STEEL MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1918	15,700	15,700	0
1923	3,190	3,190	0
1940	0	0	0
TOTAL	18,890	18,890	0

METERS

⅜-IN. ROTARY METERS

Year Installed	Number		
	Installed	In Service	Retired
1913	1	0	1
1940	0	0	0
TOTAL	1	0	1

Retirements by Years

Year Installed	Number	Year
1913	1	1935

½-IN. ROTARY METERS

Year Installed	Number		
	Installed	In Service	Retired
1930	7	7	0
1940	0	0	0
TOTAL	7	7	0

⅝-IN. ROTARY METERS

Year Installed	Number		
	Installed	In Service	Retired
1915	123	118	5
1918	25	25	0
1919	170	146	24
1921	1	1	0
1925	1	1	0
1926	49	48	1
1930	17	17	0
1932	7	7	0
1933	1	0	1
1936	1	1	0
1939	3	3	0
1940	0	0	0
SUBTOTAL	398	367	31
Unknown	35	0	35
TOTAL	433	367	66

⅝-in. Rotary Meters (contd.)

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1915	1	1926	3	1936	1	1938
1919	4	1932	4	1933	5	1934
	4	1935	3	1936	3	1939
	1	1940				
1926	1	1934				
1933	1	1940				
Unknown	24—Sold, believed still in service.					
	11—Returned to factory.					

¾-in. Rotary Meters

Year	Number		
Installed	Installed	In Service	Retired
1914	1	0	1
1915	21	21	0
1920	15	15	0
1923	9	9	0
1924	83	81	2
1930	4	4	0
1932	1	1	0
1936	2	2	0
1940	0	0	0
Subtotal	136	133	3
Unknown	15	0	15
Total	151	133	18

Retirements by Years

Year Installed	Number	Year	Number	Year
1914	1	1935		
1924	1	1933	1	1940
Unknown	14—Sold, believed still in service.			
	1—Returned to factory.			

1-in. Rotary Meters

Year	Number		
Installed	Installed	In Service	Retired
1915	17	17	0
1924	29	29	0
1925	9	9	0
1940	0	0	0
Subtotal	55	55	0
Unknown	3	0	3
Total	58	55	3

1-in. Rotary Meters (contd.)

Retirements by Years

Year Installed	Number	Year
Unknown	3—Sold, believed still in service.	

1¼-in. Rotary Meters

Year	Number		
Installed	Installed	In Service	Retired
1932	2	2	0
1940	0	0	0
Subtotal	2	2	0
Unknown	1	0	1
Total	3	2	1

Retirements by Years

Years Installed	Number	Year
Unknown	1—Sold, believed still in service.	

1½-in. Rotary Meters

Year	Number		
Installed	Installed	In Service	Retired
1915	1	1	0
1924	7	5	2
1925	1	1	0
1931	3	3	0
1940	0	0	0
Subtotal	12	10	2
Unknown	3	0	3
Total	15	10	5

Retirements by Years

Year Installed	Number	Year
1924	2	1939
Unknown	3—Sold, believed still in service.	

2-IN. ROTARY METERS

Year Installed	Number Installed	Number In Service	Number Retired
1915	12	12	0
1921	5	5	0
1940	0	0	0
SUBTOTAL	17	17	0
Unknown	11	0	11
TOTAL	28	17	11

Retirements by Years

Year Installed	Number	Year
Unknown	11—Returned to factory.	

3-IN. ROTARY METERS

Year Installed	Number Installed	Number In Service	Number Retired
1915	7	7	0
1919	1	0	1
1925	2	2	0
1930	2	2	0
1940	0	0	0
SUBTOTAL	12	11	1
Unknown	2	0	2
TOTAL	14	11	3

3-IN. ROTARY METERS (contd.)

Retirements by Years

Year Installed	Number	Year
1919	1	1929
Unknown	2—Sold, believed still in service.	

4-IN. ROTARY METERS

Year Installed	Number Installed	Number In Service	Number Retired
1915	1	1	0
1919	1	0	1
1940	0	0	0
TOTAL	2	1	1

Retirements by Years

Year Installed	Number	Year
1919	1	1929

6-IN. ROTARY METERS

Year Installed	Number Installed	Number In Service	Number Retired
1915	3	3	0
1940	0	0	0
TOTAL	3	3	0

⅝-IN. DISC METERS

Year Installed	Number Installed	Number In Service	Number Retired
1901	2	0	2
1902	32	5	27
1903	5	0	5
1906	3	3	0
1914	1	1	0
1916	1	0	1
1919	2	1	1
1921	100	96	4
1922	73	73	0
1923	98	97	1
1924	123	122	1
1925	99	99	0
1926	1	1	0
1927	52	52	0
1928	6	6	0
1929	4	4	0
1930	187	187	0
1932	98	98	0
1934	11	11	0
1935	25	25	0
1937	12	12	0
1940	0	0	0
SUBTOTAL	935	893	42
Unknown	73	0	73
TOTAL	1,008	893	115

⅝-in. Disc Meters (contd.)

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1901	1	1933	1	1936		
1902	2	1932	9	1933	12	1935
	1	1936	3	1939		
1903	2	1933	1	1936	2	1939
1916	1	1933				

Year Installed	Number	Year	Number	Year	Number	Year
1919	1	1935				
1921	3	1934	1	1939		
1923	1	1936				
1924	1	1939				
Unknown	73—Sold, believed still in service.					

¾-in. Disc Meters

Year Installed	Number Installed	In Service	Retired
1901	2	1	1
1902	2	0	2
1903	4	0	4
1918	32	32	0
1921	2	0	2
1922	21	21	0
1923	18	18	0
1925	120	120	0
1927	2	2	0
1928	3	3	0
1930	33	33	0
1931	9	9	0

Year Installed	Number Installed	In Service	Retired
1932	89	89	0
1936	9	9	0
1937	26	26	0
1938	10	10	0
1939	17	17	0
1940	2	2	0
Subtotal	401	392	9
Unknown	138	0	138
Total	539	392	147

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1901	1	1936				
1902	1	1935	1	1939		
1903	1	1911	1	1933	1	1936
	1	1938				

Year Installed	Number	Year	Number	Year	Number	Year
1921	2	1934				
Unknown	138—Sold, believed still in service.					

1-in. Disc Meters

Year Installed	Number Installed	In Service	Retired
1901	3	0	3
1902	7	0	7
1905	2	2	0
1906	5	3	2
1911	2	2	0
1912	2	2	0
1914	4	4	0
1915	1	1	0
1918	33	31	2
1919	20	20	0
1921	24	23	1
1922	21	21	0
1923	23	23	0

Year Installed	Number Installed	In Service	Retired
1924	25	24	1
1925	30	30	0
1927	16	16	0
1928	2	2	0
1930	18	18	0
1932	47	47	0
1940	0	0	0
Subtotal	285	269	16
Unknown	39	0	39
Total	324	269	55

1-in. Disc Meters (contd.)

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1901	1	1933	2	1939		
1902	3	1933	1	1934	1	1935
	2	1939				
1906	2	1933				
1918	1	1935	1	1936		
1921	1	1935				
1924	1	1935				

Unknown 39—Sold, believed still in service.

1¼-in. Disc Meters

Year Installed	Number Installed	In Service	Retired
1919	10	9	1
1930	2	2	0
1932	2	2	0
1940	0	0	0
Subtotal	14	13	1
Unknown	4	0	4
Total	18	13	5

Retirements by Years

Year Installed	Number	Year
1919	1	1933

Unknown 4—Sold, believed still in service.

1½-in. Disc Meters

Year Installed	Number Installed	In Service	Retired
1908	1	1	0
1909	1	0	1
1918	5	5	0
1919	12	12	0
1922	13	13	0
1923	8	8	0
1924	1	1	0
1925	7	7	0
1929	4	4	0
1930	9	9	0
1931	3	3	0
1902	23	23	0
1936	3	3	0
1937	3	3	0
1938	11	11	0
1939	3	3	0
1940	6	6	0
Subtotal	113	112	1
Unknown	11	0	11
Total	124	112	12

1½-in. Disc Meters (contd.)

Retirements by Years

Year Installed	Number	Year
1909	1	1928

Unknown 11—Sold, believed still in service.

2-in. Disc Meters

Year Installed	Number Installed	In Service	Retired
1901	1	0	1
1908	1	1	0
1909	2	2	0
1912	3	3	0
1918	10	10	0
1922	32	32	0
1923	20	20	0
1924	50	50	0
1925	22	22	0
1927	14	14	0
1930	12	11	1
1932	47	47	0
1940	0	0	0
Subtotal	214	212	2
Unknown	7	0	7
Total	221	212	9

2-IN. DISC METERS (contd.)

Retirements by Years

Year Installed	Number	Year
1901	1	1932
1930	1	1936
Unknown	7—Sold, believed still in service.	

3-IN. DISC METERS

Year Installed	Number		
	Installed	In Service	Retired
1924	6	6	0
1925	8	8	0
1927	6	5	1
1930	3	3	0
1933	1	1	0
1934	4	4	0
1935	1	1	0
1936	3	3	0
1937	1	1	0
1940	0	0	0
TOTAL	33	32	1

Retirements by Years

Year Installed	Number	Year
1927	1	1934

1½-IN. COMPOUND METERS

Year Installed	Number		
	Installed	In Service	Retired
1919	1	1	0
1940	0	0	0
TOTAL	1	1	0

2-IN. COMPOUND METERS

Year Installed	Number		
	Installed	In Service	Retired
1919	1	1	0
1921	24	24	0
1940	0	0	0
TOTAL	25	25	0

3-IN. COMPOUND METERS

Year Installed	Number		
	Installed	In Service	Retired
1919	1	1	0
1920	1	1	0
1921	17	17	0
1922	6	6	0
1923	6	6	0
1940	0	0	0
TOTAL	31	31	0

4-IN. COMPOUND METERS

Year Installed	Number		
	Installed	In Service	Retired
1915	3	3	0
1921	6	6	0
1922	4	4	0
1923	4	4	0
1927	5	5	0
1940	0	0	0
TOTAL	22	22	0

6-IN. COMPOUND METERS

Year Installed	Number		
	Installed	In Service	Retired
1915	3	3	0
1918	2	2	0
1920	4	4	0
1922	2	2	0
1923	4	4	0
1924	2	2	0
1927	3	3	0
1930	4	4	0
1940	0	0	0
SUBTOTAL	24	24	0
Unknown	4	0	4
TOTAL	28	24	4

Retirements by Years

Year Installed	Number	Year
Unknown	4—Sold, believed still in service.	

8-IN. COMPOUND METERS

Year Installed	Number Installed	Number In Service	Number Retired
1915	1	1	0
1918	1	1	0
1920	1	1	0
1922	1	1	0
1924	2	2	0
1927	2	2	0
1932	2	2	0
1940	0	0	0
SUBTOTAL	10	10	0
Unknown	7	0	7
TOTAL	17	10	7

Retirements by Years

Year Installed	Number	Year
Unknown	7—Sold, believed still in service.	

1½-IN. CURRENT METERS

Year Installed	Number Installed	Number In Service	Number Retired
1914	2	2	0
1940	0	0	0
SUBTOTAL	2	2	0
Unknown	1	0	1
TOTAL	3	2	1

Retirements by Years

Year Installed	Number	Year
Unknown	1—Sold, believed still in service.	

2-IN. CURRENT METERS

Year Installed	Number Installed	Number In Service	Number Retired
1907	2	0	2
1909	2	0	2
1911	2	0	2
1912	9	0	9
1914	7	6	1
1919	4	4	0

2-IN. CURRENT METERS (contd.)

Year Installed	Number Installed	Number In Service	Number Retired
1920	26	26	0
1940	0	0	0
SUBTOTAL	52	36	16
Unknown	3	0	3
TOTAL	55	36	19

Retirements by Years

Year Installed	Number	Year
1907	2	1932
1909	2	1935
1911	2	1932
1912	9	1933
1914	1	1933
Unknown	3—Sold, believed still in service.	

3-IN. CURRENT METERS

Year Installed	Number Installed	Number In Service	Number Retired
1905	3	1	2
1907	3	1	2
1908	1	1	0
1910	2	2	0
1911	2	2	0
1912	6	6	0
1918	7	7	0
1919	7	7	0
1920	5	5	0
1925	1	1	0
1940	0	0	0
SUBTOTAL	37	33	4
Unknown	4	0	4
TOTAL	41	33	8

Retirements by Years

Year Installed	Number	Year	Number	Year
1905	1	1932	1	1933
1907	2	1932		
Unknown	4—Sold, believed still in service.			

4-IN. CURRENT METERS

Year Installed	Number Installed	In Service	Retired
1904	1	1	0
1905	1	0	1
1907	2	2	0
1911	2	2	0
1912	5	5	0
1915	1	0	1
1918	2	2	0
1919	1	1	0
1920	20	20	0
1940	0	0	0
SUBTOTAL	35	33	2
Unknown	1	0	1
TOTAL	36	33	3

Retirements by Years

Year Installed	Number	Year
1905	1	1934
1915	1	1930
Unknown	1—Sold, believed still in service.	

6-IN. CURRENT METERS

Year Installed	Number Installed	In Service	Retired
1906	1	1	0
1911	4	4	0
1919	2	2	0
1920	10	10	0
1924	3	3	0
1940	0	0	0
TOTAL	20	20	0

8-IN. CURRENT METERS

Year Installed	Number Installed	In Service	Retired
1919	2	2	0
1920	2	2	0
1940	0	0	0
TOTAL	4	4	0

Des Moines, Iowa—Survival and Retirement Experience With Water Works Facilities

As of December 31, 1942

THE Des Moines Water Works System is a municipally-owned water plant serving the city of Des Moines, Iowa, and contiguous area. The city is the state capital and is important as a distribution, manufacturing and office center. The water plant also serves Fort Des Moines, south of the city, at present one of the Women's Army Corps' training centers. Des Moines is located at the confluence of the Des Moines and Raccoon rivers. Within the service territory at the date of the study there were 38,824 services furnishing water to an estimated 179,853 people. Consumption during 1942 averaged 15.5 mgd. or about 86 gpd. per capita.

Development of the Existing System

The Des Moines Water Works was started in 1871 by the Des Moines Water Co. and continued as a private organization until its purchase by the city in 1919. Records concerning the source and character of the original supply before 1884 are obscure. In 1884 a new supply was obtained from an infiltration gallery along the north side of the Raccoon River. It terminated in a suction well at a pumping station located at 16th and Walnut Streets. The original infiltration gallery consisted of 1,077 ft. of conduit, 4 ft. × 5 ft. in section, constructed of wood plank surrounded by crushed stone. Additions to the original gallery were made at numerous dates, as shown in Table 5. In 1887, Gallery No. 2 and a river well connected to it were built to secure water from the Raccoon River.

In the years 1923–1924 and 1932 the present supply was further developed on the south side of the river. Galleries 1, 2 and a part of Gallery 3, together with the suction wells and the pumping station and equipment at 16th and Walnut Streets, were abandoned in 1922. The new supply similarly consists of an infiltration gallery, constructed of concrete and steel ring sections 48 and 60 in. in diameter, set on cradles and surrounded by gravel jackets. A portion of the old wooden gallery is connected and still in service. A total of approximately 18,600 ft. of collecting gallery is in service.

Another flooding station at 28th Street, first put into service in 1918, is also used by pumping from Raccoon River for flooding a portion of the area over the collecting gallery at low stages of the river.

The four main pumping units in the old plant at 16th and Walnut Streets were steam-engine-driven, horizontal compound units installed in 1883, 1884, 1902 and 1910 and retired in 1921 upon the construction of the 21st Station. The four main units at the 21st Station installed in 1920, 1921, 1922 and 1928 are still in service.

From the pumping station the water is pumped directly into the distribution system in a single service with a 2-mil. gal. elevated tank as an equalizer. Pumping heads at the station average

TABLE 1

SUMMARY OF MAINS

DES MOINES, IOWA

Size, *in.*	Kind	No. of Feet Installed	No. of Feet Identified	Percentage of Total	No. of Feet Retired	Percentage of Total	No. of Feet in Service	Percentage of Total	Year of First Installation	Average Age, *yr.*
30	Steel	1,826	1,826	0.09	0	0	1,826	0.09	1936	6.5
12	Steel	742	742	0.04	0	0	742	0.04	1940	2.5
30	Cast-iron unlined	18,004	18,004	0.86	2,226	19.51	15,778	0.76	1920	10.3
24		6,409	6,409	0.31	9	0.08	6,400	0.31	1922	19.0
20		45,715	45,715	2.20	1,216	10.66	44,499	2.15	1883	17.2
16		38,431	34,403	1.65	365	3.20	34,038	1.64	1883	25.5
14		36,477	36,477	1.75	0	0	36,477	1.76	1941	1.5
12		188,975	185,711	8.92	370	3.24	185,341	8.96	1888	26.1
10		6,305	1,355	0.07	0	0	1,355	0.06	1896	46.5
8		1,561,267	1,488,250	71.52	4,895	42.90	1,483,355	71.68	1884	23.6
6		327,970	261,499	12.57	1,956	17.15	259,543	12.54	1881	29.5
4		18,312	501	0.02	372	3.26	129	0.01	1881	23.2
TOTAL		2,250,433	2,080,892	100.00	11,409	100.00	2,069,483	100.00		23.9
Percentage of Total			100.0		0.62		99.38			
Average Size, *in.*			8.87		12.68		8.84			

Mortality Survival Ratios
Cast-Iron Unlined Pipe

Size, *in.*	No. of Feet	Period Covered, *yr.*	Percentage
4	501	61.5	7.000
6	261,499	61.5	97.455
8	1,488,250	58.5	98.507
10–12	187,066	54.5	99.604
Over 12	141,008	59.5	81.902
TOTAL	2,078,324		

about 120 psi. There are in the distribution system, exclusive of hydrant branches, approximately 420 mi. of pipe ranging from 4 to 30 in. in diameter. The greater portion of the system consists of Class B, tar-coated, bell-and-spigot, cast-iron pipe, generally laid with a cover of 5 ft.

There are 38,824 service connections which, with the exception of the larger cast-iron services and recent copper installations, are of lead. The system has 2,863 valves, 3,665 hydrants and 38,639 meters. Of the total number of facilities installed 2,588 valves, 3,733 hydrants and 40,704 meters were identified as to the year installed. The services are approximately 100 per cent metered with 84 per cent of the total output of water billed through meters.

TABLE 2

SUMMARY OF VALVES
DES MOINES, IOWA

Size, in.	Number Installed	Number Identified	Number Retired	Number in Service	Year of First Installation	Average Age, yr.	Number Salvaged
4	59	13	0	13	1884	26.3	—
6	624	501	0	501	1881	29.3	—
8	1,891	1,791	4	1,787	1884	23.4	3
10	8	3	0	3	1896	46.5	—
12	170	164	2	162	1888	25.4	2
14	14	14	0	14	1941	1.5	—
16	37	34	3	31	1883	29.9	3
20	36	35	0	35	1883	20.4	—
24	7	7	0	7	1922	19.1	—
30	27	26	1	25	1921	12.1	1
TOTAL	2,873	2,588	10	2,578		24.5	
Percentage of Total		100.00	0.39	99.61			

NOTE: With one exception all valves shown as retired were removed, salvaged and used again. One 8-in. valve, retired because of sewer construction, was abandoned.

Mortality Survival Ratios

Size, in.	Number	Period Covered, yr.	Percentage
4	13	58.5	100.000
6	501	61.5	100.000
8	1,791	58.5	99.376
10 and 12	167	53.5	95.905
Over 12	116	59.5	86.789
TOTAL	2,588		

Basis of Study

The records of installation and retirement of pipe and valves are stated to be complete from 1912 to date. From 1871 to 1882 the footage of pipe laid is largely unknown. From plat books, field notes and other records the retirements of pipe since 1882 have been secured. Prior to 1882 the retirement date is obscure so that pipe installations made in the period from 1871 to 1882, which are still in service, have been called unidentified and have been eliminated from the mortality study. It is stated that most of the pipe originally laid in this period is still in service. Annual reports are available from 1913 to the present date.

The records of meters and hydrants are substantially complete from 1880 to the present, as are those of pipe and valves. The installation and retirement of Class B facilities from 1882 to date could be accurately secured from the various basic records available.

The work of abstracting the records of installation and retirement of mains, valves, meters, hydrants and Class B facilities was carried out by the regular staff of the department.

TABLE 3

SUMMARY OF METERS

DES MOINES, IOWA

Size, *in.*	Kind	Number Installed	Number Identified	Number Retired	Number in Service	Average Age, *yr.*
⅝	Disc	37,505	37,493	466	37,027	23.2
¾		303	302	4	298	16.2
1		422	422	11	411	25.5
1½		152	152	15	137	21.1
2		311	311	34	277	20.3
⅝	Rotary	1,896	1,853	1,610	243	44.5
¾		68	55	55	0	—
1		26	23	23	0	—
1½		9	8	8	0	—
2		40	39	39	0	—
3		3	3	3	0	—
4		2	1	1	0	—
3	Proportion	6	6	1	5	23.1
4		5	5	5	0	—
6		5	5	4	1	25.5
3	Torrent	5	5	2	3	33.8
4		6	6	3	3	36.5
6		4	4	2	2	34.5
3	Compound	2	2	0	2	25.5
4		3	3	0	3	22.2
6		6	6	1	5	2.9
TOTAL		40,779	40,704	2,287	38,417	23.3

Mortality Survival Ratios

Size, *in.*	Kind	Number	Period Covered, *yr.*	Percentage
⅝	Disc	37,493	52.5	91.344
⅝	Rotary	1,853	60.5	3.267
¾–2	Disc	1,187	42.5	89.136
¾–4	Rotary	129	53.5	0
Others		42	46.5	0
TOTAL		40,704		

TABLE 4

SUMMARY OF HYDRANTS

DES MOINES, IOWA

Number Installed	Number Identified	Number Retired	Number in Service	Average Age, *yr.*	Period Covered, *yr.*	Mortality Survival Ratio, %
4,061	3,733	279	3,454	24.3	61.5	68.036

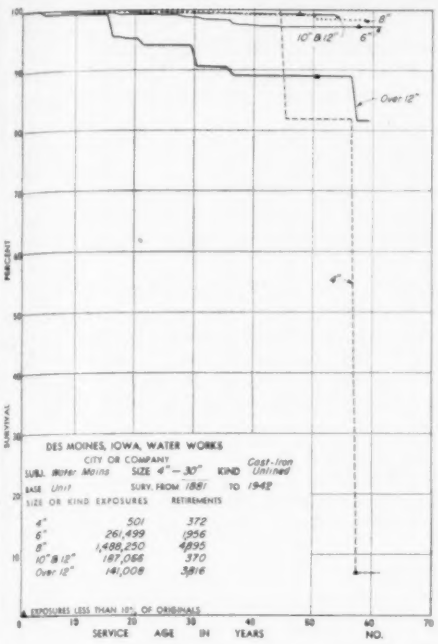
DES MOINES, IOWA, WATER WORKS
CITY OR COMPANY
SUBJ. Water Mains SIZE 4" – 30" KIND Cast-Iron Unlined
BASE Unit SURV. FROM 1881 TO 1942
SIZE OR KIND EXPOSURES RETIREMENTS
4" 501 372
6" 261,499 1956
8" 1,488,250 4895
10" & 12" 187,066 370
Over 12" 141,008 3816
EXPOSURES LESS THAN 10% OF ORIGINALS
SURVIVAL
PERCENT
SERVICE AGE IN YEARS
NO.

FIGURE 1

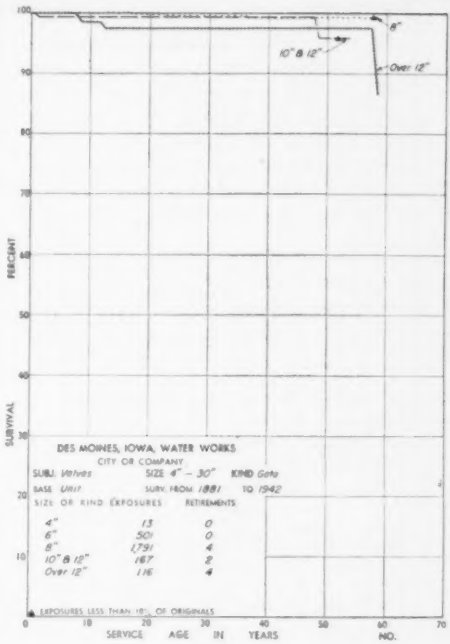

FIGURE 2

Mortality Survival Study

Mortality studies were made of mains, valves, meters and hydrants. Table 1 is a summary of the pipe installed, the amount identified, retirements of identified pipe and pipe still in service, as well as their average ages, length of record, mortality survival ratios and average sizes. Figure 1 shows the mortality survival curves covering the record of the amount and sizes of pipe grouped as shown.

Tables 2, 3 and 4 are similar summaries of gate valves, meters and hydrants with Figs. 2, 3 and 4 representing the applicable mortality survival curves.

Causes of Retirement

The causes of retirement of mains are given in Table 5. Old pipe taken up has shown almost no tuberculation or corrosion. Of the total retirements of water mains approximately 33.3 per cent were because of inadequacy, 45.1 per cent because of other construction by public authorities and 21.6 per cent because of other factors, including 18.4 per cent which could not definitely be determined from the records. Approximately 51.5 per cent of the total footage of mains retired which could definitely be identified were salvaged and re-used.

The retirement of gate valves was almost entirely dependent upon the retirement of mains in which they were located. Except for the abandonment of one 8-in. valve, valves retired were removed, repaired and again used at other locations.

It was not possible to ascertain definite reasons for the retirement of individual meters. As a matter of policy rotary meters have not been installed

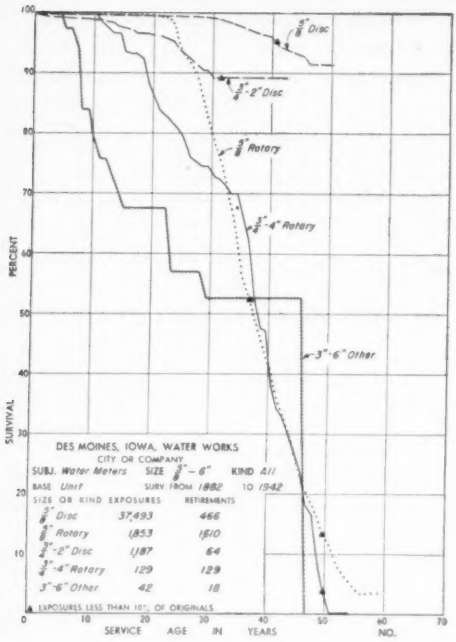
PERCENT SURVIVAL
DES MOINES, IOWA, WATER WORKS
CITY OR COMPANY
SUBJ. Water Meters SIZE ⅝"–6" KIND All
BASE Unit SURV. FROM 1882 TO 1942
SIZE OR KIND EXPOSURES RETIREMENTS
⅝" Disc 37,493 466
⅝" Rotary 1,853 1,510
¾"-2" Disc 1,187 64
¾"-4" Rotary 129 129
3"-6" Other 42 18
EXPOSURES LESS THAN 10% OF ORIGINALS
SERVICE AGE IN YEARS
NO.

FIGURE 3

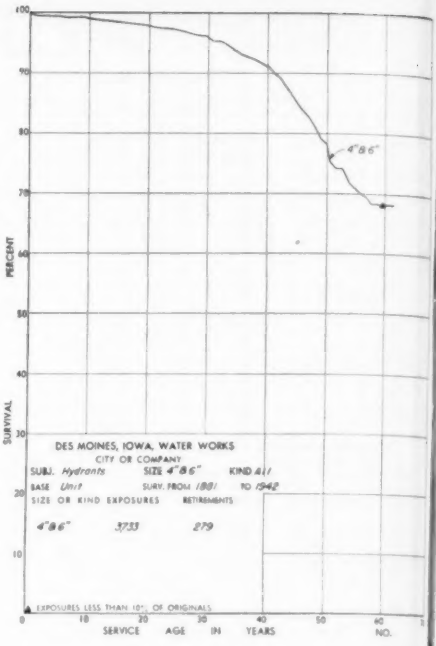
PERCENT SURVIVAL
DES MOINES, IOWA, WATER WORKS
CITY OR COMPANY
SUBJ. Hydrants SIZE 4"&6" KIND All
BASE Unit SURV. FROM 1881 TO 1942
SIZE OR KIND EXPOSURES RETIREMENTS
4"&6" 3733 279
EXPOSURES LESS THAN 10% OF ORIGINALS
SERVICE AGE IN YEARS
NO.

FIGURE 4

in any number since 1900 and those previously installed have been retired more generously than other types to secure uniformity in the type and kind of meters in service.

No definite record has been kept of the causes dictating the retirement of hydrants by sizes. While the record reflects the retirement of hydrants whenever taken out, it is stated that in the greater percentage of retirements the hydrants taken out were repaired and used again in other locations.

Acknowledgments

The collection and compilation of data in Des Moines were under the general supervision of Dale L. Maffitt, General Manager and a member of the Committee on Survival and Retirement Experience With Water Works Facilities. R. B. Wood, Office Engineer; H. King Dawson, Assistant Office Engineer; and W. E. Bjork, Superintendent of the Meter Department, were in charge of abstracting the records.

Summary of Class B Facilities

Des Moines, Iowa

Infiltration Galleries

No. 1—Rectangular gallery, 4 ft. × 5 ft. in section, 1,077 ft. long, of wood construction, surrounded by crushed stone. Constructed in 1884–1886 and retired in 1922 when a new supply in a different location was constructed.

No. 2—Similar gallery of same type of construction, 4 ft. × 3½ ft. in section, 1,594 ft. long. Constructed in 1887 and retired in 192 when new supply was constructed.

No. 3—Similar gallery of same type of construction, 5 ft. × 3 ft. in section, 1,250 ft.

SUMMARY OF CLASS B FACILITIES (contd.)

long. Constructed in 1894; 432 ft. abandoned in 1922 when new supply was constructed but 818 ft. was connected to the new galleries and is still in service.

No. 4—Similar gallery of same type of construction, 5 ft. × 3½ ft. in section, 1,000 ft. long. Constructed in 1904 and still in service, together with a cross-connection of 20-in. cast-iron pipe, 430 ft. long, between gallery Nos. 3 and 4.

No. 5—Circular gallery of reinforced concrete, 4-ft. id., set on cradles consisting of 3,194 ft. of rings with 108 ft. of cast-iron pipe, and surrounded with crushed tile. Constructed in 1910–1911 and still in service.

No. 6—Similar gallery to No. 5, 4-ft. id., 3,398 ft. of rings with 72 ft. of cast-iron pipe. Constructed in 1914–1916 and still in service.

No. 7—Steel and concrete gallery, 4-ft. id., 5,000 ft. of rings, set on cradles with loose gravel jacket. Constructed in 1923–1924 and still in service.

No. 8—Similar gallery, 5-ft. id., 4,600 ft. long. Constructed in 1932 and still in service.

Tunnel No. 1—The pumping station end of the filter galleries consists of 6-ft. arched monolithic concrete tunnel, 2,510 ft. long, constructed in 1927–1928 and still in service.

Wells

Suction Well—Brick well, 46 ft. 8 in. in diameter, 31 ft. deep, cased for 26 ft. in depth forming suction well for gallery supply. Constructed in 1882 and retired in 1922 when new supply was developed.

River Well—Brick well, 20 ft. in diameter, 22 ft. deep, used for pump suction well. Constructed in 1887 and retired in 1922 when new supply was developed.

Siphon Well—Brick well, 16 ft. 8 in. in diameter, 44 ft. 2 in. deep, 20-in. reinforced brick masonry walls. Constructed in 1904 and retired in 1922 when new supply was developed.

Suction Well—Reinforced concrete pump suction well, 100 ft. × 12 ft. in plan, 25 ft. deep. Constructed in 1922 and still in service.

Pumping Equipment

Old Station

Gaskill 6-mgd., horizontal, compound steam-engine pumping unit; 80-lb. domestic and 140-lb. fire pressure; installed 1883; retired 1921 with construction of new plant.

Worthington 6-mgd., horizontal, compound steam-engine pumping unit; 80-lb. domestic and 135-lb. fire pressure; installed 1884; retired 1921 with construction of new plant.

Holly-Gaskill 8-mgd., horizontal, compound condensing steam-engine pumping unit; 110-lb. domestic and 140-lb. fire pressure; installed 1902; retired 1921 with construction of new plant.

Snow 10-mgd., horizontal, cross compound steam-engine pumping unit; 108-lb. domestic and 150-lb. fire pressure; installed 1910; retired 1921 with construction of new plant.

New Station

No. 1—DeLaval geared, steam-turbine-driven pumping unit, 15-mgd. capacity, 269-ft. head, 1,100 hp.; installed 1920 and still in service.

No. 2—Similar DeLaval unit; installed 1921 and still in service.

No. 3—DeLaval geared, steam-turbine-driven pumping unit, 25-mgd. capacity, 269-ft. head, 1,424 hp.; installed 1922 and still in service.

No. 4—DeLaval geared, steam-turbine-driven pumping unit, 30-mgd. capacity, 280-ft. head, 1,750 hp.; installed 1928 and still in service.

Field Stations

No. 1—Horizontal, motor-driven centrifugal pumping unit, 5-mgd. capacity, 18-ft. head, 25-hp. motor; installed 1918 and still in service.

No. 2—Similar to No. 1.

No. 3—Horizontal, motor-driven centrifugal pumping unit, 10-mgd. capacity, 18-ft. head, 40-hp. motor; installed 1926 and still in service.

Sand Plant—Horizontal, motor-driven centrifugal pumping unit, 1.5-mgd. capacity, 15-ft. head, 7½-hp. motor; installed 1932 and still in service.

Tanks and Standpipes

17th Street Standpipe—30 ft. in diameter by 100 ft. high; 530,000-gal. capacity; boiler steel; erected 1890; retired 1940 because of inadequate capacity and not in condition for enlarging.

Allen Hazen Elevated Tank—110-ft. diameter by 28.6-ft. depth on 73.7-ft. tower to flow line; capacity 2 mil. gal.; erected 1930–1931 and still in service.

TABLE 5

CAUSES OF RETIREMENT OF MAINS
DES MOINES, IOWA

Size, *in.*	Kind	Length, *ft.*	Life, *yr.*	Cause of Retirement	Salvage, *ft.*
4	Cast-iron unlined	300	57.5	Replaced by 8-in. main	0
		72	44.5	Replaced by 8-in. main	0
		372			0
6	Cast-iron unlined	257	11.5	Replaced by 8-in. main	0
		180	39.5	Replaced by 8-in. main	180
		450	28.5	State Capitol construction	0
		371	31.5		0
		20	36.5		20
		678	36.5	Change in street grade	300
		180	7.5	Unknown	0
		168	14.5		0
		181	17.5		0
		169	24.5		0
		181	27.5		0
		169	34.5		0
		181	37.5		0
		169	44.5		0
		3,354			500
8	Cast-iron unlined	55	15.5	Underpass construction	55
		1,077	27.5	Underpass construction	1,077
		400	18.5	Change in street grade	400
		200	17.5	Replaced by 12-in. main	200
		798	30.5		798
		1,190	50.5		0
		279	36.5	Replaced by 12- and 16-in. mains	0
		818	13.5	Replaced by 12-in. main	818
		78	16.5	Abandoned service	78
		4,895			3,426
12	Cast-iron unlined	202	28.5	Viaduct construction	202
		168	19.5	Replaced by 24-in. main	0
		370			
16	Cast-iron unlined	365	57.5	Replaced by 20-in. main	365
		365			365
20	Cast-iron unlined	700	30.5	River crossing	0
		220	21.5	Abandonment of old pump station	220
		296	46.5	Unknown	0
		1,216			220
24	Cast-iron unlined	9	18.5	Replaced by 20-in. main	9
		9			9
30	Cast-iron unlined	276	4.5	Dam failure	276
		1,950	16.5	Relocation of river crossing	1,600
		2,226			1,876
TOTAL		12,807			6,598

SUMMARY OF INSTALLATIONS AND RETIREMENTS
DES MOINES, IOWA

MAINS

4-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1881	400	28	372
1923	15	15	0
1926	34	34	0
1934	44	44	0
1937	8	8	0
1942	0	0	0
SUBTOTAL	501	129	372

Year Installed	Feet Installed	Feet In Service	Feet Retired
Unknown	17,811	16,519	1,292
TOTAL	18,312	16,648	1,664

Retirements by Years

Year Installed	Feet	Year	Feet	Year
1881	72	1925	300	1938

6-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1881	676	676	0
1883	787	787	0
1884	19,276	18,885	391
1885	2,703	2,703	0
1886	14,917	14,059	858
1887	28,464	28,014	450
1888	17,021	17,021	0
1889	4,202	4,202	0
1890	4,856	4,856	0
1891	745	745	0
1892	3,211	3,211	0
1895	956	956	0
1896	413	413	0
1898	2,313	2,313	0
1899	4,655	4,655	0
1900	1,669	1,669	0
1901	2,089	2,089	0
1902	172	172	0
1903	4,509	4,509	0
1904	6,544	6,544	0
1905	542	542	0
1906	1,295	1,295	0
1907	48	48	0
1909	1,072	1,072	0
1910	2,427	2,427	0
1911	4,426	4,426	0
1912	2,105	2,105	0
1913	478	478	0
1914	3,500	3,243	257

Year Installed	Feet Installed	Feet In Service	Feet Retired
1915	1,703	1,703	0
1916	166	166	0
1918	815	815	0
1920	12	12	0
1921	285	285	0
1922	3	3	0
1923	1,583	1,583	0
1924	6,874	6,874	0
1925	5,725	5,725	0
1926	91	91	0
1927	2,415	2,415	0
1928	782	782	0
1929	571	571	0
1930	307	307	0
1931	5,514	5,514	0
1932	6,278	6,278	0
1934	8,807	8,807	0
1935	242	242	0
1937	14,378	14,378	0
1938	19,668	19,668	0
1939	20,691	20,691	0
1940	14,671	14,671	0
1941	10,995	10,995	0
1942	2,852	2,852	0
SUBTOTAL	261,499	259,543	1,956
Unknown	66,471	65,073	1,398
TOTAL	327,970	324,616	3,354

Retirements by Years

Year Installed	Feet	Year	Feet	Year
1884	371	1915	20	1920
1886	678	1922	180	1925

Year Installed	Feet	Year
1887	450	1915
1914	257	1925

8-in. Cast-Iron Unlined Mains

Year Installed	Feet			Year Installed	Feet		
	Installed	In Service	Retired		Installed	In Service	Retired
1884	6,125	6,125	0	1916	47,293	47,293	0
1886	10,876	10,876	0	1917	23,870	23,870	0
1887	7,526	7,526	0	1918	16,303	16,303	0
1888	20,200	19,010	1,190	1919	68	68	0
1889	12,613	12,613	0	1920	16,733	16,733	0
1890	36,412	36,133	279	1921	36,287	36,087	200
1891	26,517	26,517	0	1922	25,844	25,844	0
1892	15,249	15,249	0	1923	53,373	53,373	0
1893	781	781	0	1924	90,942	90,942	0
1894	6,907	6,907	0	1925	89,246	89,168	78
1895	2,698	2,698	0	1926	126,670	126,615	55
1896	4,770	4,770	0	1927	13,881	13,881	0
1897	6,726	6,726	0	1928	4,665	4,665	0
1898	8,649	8,649	0	1929	28,540	28,540	0
1899	1,403	1,403	0	1930	3,811	3,811	0
1900	10,752	10,752	0	1931	78,961	78,961	0
1901	8,867	8,867	0	1932	7,212	7,212	0
1902	8,650	8,650	0	1934	34,103	34,103	0
1903	12,444	12,444	0	1935	57	57	0
1904	43,619	43,219	400	1936	12,178	12,178	0
1905	22,819	22,819	0	1937	33,646	33,646	0
1906	10,276	10,276	0	1938	53,414	53,414	0
1907	23,173	21,557	1,616	1939	56,322	56,322	0
1908	8,028	8,028	0	1940	29,280	29,280	0
1909	20,496	20,496	0	1941	23,729	23,729	0
1910	17,336	17,336	0	1942	9,046	9,046	0
1911	37,196	37,196	0				
1912	39,394	39,394	0	Subtotal	1,488,250	1,483,355	4,895
1913	36,476	36,476	0	Unknown	73,017	64,110	8,907
1914	46,154	45,077	1,077				
1915	59,644	59,644	0	Total	1,561,267	1,547,465	13,802

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Year Installed	Feet	Year
1888	1,190	1938			1914	1,077	1941
1890	279	1926			1921	200	1938
1904	400	1922			1925	78	1941
1907	818	1920	798	1937	1926	55	1941

10-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1896	1,355	1,355	0
1942	0	0	0
Subtotal	1,355	1,355	0
Unknown	4,950	4,400	550
Total	6,305	5,755	550

12-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1888	1,226	1,226	0
1889	1,371	1,371	0
1890	5,149	5,149	0
1891	3,459	3,459	0
1892	1,618	1,618	0
1893	1,055	1,055	0
1894	1,172	1,172	0
1895	1,665	1,665	0
1896	4,850	4,648	202
1898	1,088	1,088	0
1899	3,279	3,279	0
1902	17,115	17,115	0
1903	8,041	7,873	168
1904	6,088	6,088	0
1906	13,746	13,746	0
1907	149	149	0
1908	677	677	0
1909	1,429	1,429	0
1910	3,771	3,771	0
1911	2,061	2,061	0
1912	1,566	1,566	0
1913	3,489	3,489	0
1914	2,197	2,197	0
1917	2,424	2,424	0
1920	4,798	4,798	0
1921	3,419	3,419	0
1922	1,722	1,722	0
1923	1,946	1,946	0
1924	7,471	7,471	0
1925	7,222	7,222	0
1926	20,042	20,042	0
1927	23	23	0
1929	3,160	3,160	0
1931	25,671	25,671	0
1934	794	794	0
1935	13	13	0
1937	8,521	8,521	0
1938	6,241	6,241	0
1939	4,438	4,438	0
1040	1,545	1,545	0
1942	0	0	0
Subtotal	185,711	185,341	370
Unknown	3,264	3,264	0
Total	188,975	188,605	370

Retirements by Years

Year Installed	Feet	Year
1896	202	1924
1903	168	1922

12-in. Steel Mains

Year Installed	Feet		
	Installed	In Service	Retired
1940	742	742	0
1942	0	0	0
Total	742	742	0

14-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1941	36,477	36,477	0
1942	0	0	0
Total	36,477	36,477	0

16-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1883	800	435	365
1884	3,558	3,558	0
1888	807	807	0
1889	2,250	2,250	0
1901	2,561	2,561	0
1925	1,787	1,787	0
1926	14,825	14,825	0
1927	3,327	3,327	0
1934	3,843	3,843	0
1935	444	444	0
1936	58	58	0
1937	143	143	0
1942	0	0	0
Subtotal	34,403	34,038	365
Unknown	4,028	4,028	0
Total	38,431	38,066	365

Retirements by Years

Year Installed	Feet	Year
1883	365	1940

20-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1883	64	64	0
1887	1,152	156	996
1889	2,011	2,011	0
1893	4,659	4,659	0
1902	776	556	220
1904	351	351	0
1917	416	416	0
1920	24	24	0
1922	9	9	0
1929	23,100	23,100	0
1937	4,085	4,085	0
1939	8,703	8,703	0
1940	365	365	0
1942	0	0	0
Total	45,715	44,999	1,216

Retirements by Years

Year Installed	Feet	Year	Feet	Year
1887	700	1917	296	1923
1893	220	1923		

24-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1922	1,659	1,650	9
1924	4,750	4,750	0
1942	0	0	0
Total	6,409	6,400	9

Retirements by Years

Year Installed	Feet	Year
1922	9	1940

30-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1920	2,710	760	1,950
1923	2,490	2,214	276
1927	276	276	0
1929	366	366	0
1934	7,631	7,631	0
1936	2,733	2,733	0
1937	1,798	1,798	0
1942	0	0	0
TOTAL	18,004	15,778	2,226

30-IN. CAST-IRON UNLINED MAINS (contd.)

Retirements by Years

Year Installed	Feet	Year
1920	1,950	1936
1923	276	1927

30-IN. WRAPPED STEEL MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1936	1,826	1,826	0
1942	0	0	0
TOTAL	1,826	1,826	0

VALVES

4-IN. VALVES

Year Installed	Number Installed	Number In Service	Number Retired
1884	2	2	0
1887	1	1	0
1903	1	1	0
1917	1	1	0
1923	1	1	0
1927	2	2	0
1929	2	2	0
1937	3	3	0
1942	0	0	0
SUBTOTAL	13	13	0
Unknown	46	46	0
TOTAL	59	59	0

6-IN. VALVES

Year Installed	Number Installed	Number In Service	Number Retired
1881	1	1	0
1883	4	4	0
1884	26	26	0
1885	10	10	0
1886	29	29	0
1887	39	39	0
1888	31	31	0
1889	8	8	0
1890	7	7	0
1891	5	5	0
1892	10	10	0
1893	1	1	0
1894	1	1	0
1895	3	3	0
1896	1	1	0
1898	5	5	0
1899	7	7	0
1900	3	3	0
1902	5	5	0
1903	4	4	0
1904	8	8	0
1905	3	3	0
1906	4	4	0
1909	2	2	0
1910	2	2	0
1911	10	10	0
1912	5	5	0
1913	3	3	0
1914	11	11	0
1915	5	5	0
1916	1	1	0
1919	1	1	0
1920	3	3	0
1921	2	2	0
1923	4	4	0
1924	7	7	0
1925	4	4	0
1926	2	2	0
1927	2	2	0
1929	4	4	0
1930	1	1	0

6-IN. VALVES (contd.)

Year Installed	Number Installed	In Service	Retired
1931	8	8	0
1932	8	8	0
1934	14	14	0
1935	1	1	0
1936	1	1	0
1937	26	26	0
1938	42	42	0
1939	54	54	0
1940	36	36	0
1941	18	18	0
1942	9	9	0
SUBTOTAL	501	501	0
Unknown	123	123	0
TOTAL	624	624	0

8-IN. VALVES

Year Installed	Number Installed	In Service	Retired
1884	4	4	0
1886	17	17	0
1887	6	6	0
1888	21	21	0
1889	11	11	0
1890	39	39	0
1891	42	42	0
1892	15	15	0
1893	3	3	0
1894	12	11	1
1895	7	7	0
1896	7	7	0
1897	8	8	0
1898	9	9	0
1899	6	6	0
1900	11	11	0
1901	9	9	0
1902	7	7	0
1903	15	15	0
1904	52	52	0
1905	27	27	0
1906	13	13	0
1907	18	18	0
1908	13	13	0
1909	24	24	0
1910	26	26	0
1911	47	47	0
1912	51	51	0
1913	42	42	0
1914	57	57	0
1915	78	78	0
1916	77	76	1
1917	23	23	0
1918	13	13	0
1919	3	3	0
1920	24	24	0
1921	42	42	0
1922	27	26	1
1923	76	76	0
1924	77	77	0
1925	81	80	1
1926	126	126	0
1927	21	21	0
1928	8	8	0
1929	59	59	0
1930	7	7	0
1931	86	86	0
1932	8	8	0
1934	32	32	0
1936	6	6	0
1937	45	45	0
1938	96	96	0
1939	80	80	0
1940	37	37	0
1941	27	27	0
1942	13	13	0
SUBTOTAL	1,791	1,787	4
Unknown	100	97	3
TOTAL	1,891	1,884	7

Retirements by Years

Year Installed	Number	Year
1894	1	1929
1916	1	1937
1922	1	1939
1925	1	1940
Unknown	3	

10-IN. VALVES

Year Installed	Number Installed	In Service	Retired
1896	3	3	0
1942	0	0	0
	–	–	–
SUBTOTAL	3	3	0
Unknown	5	5	0
	–	–	–
TOTAL	8	8	0

12-IN. VALVES

Year Installed	Number Installed	In Service	Retired
1888	1	1	0
1889	1	1	0
1890	13	12	1
1891	5	5	0
1892	4	4	0
1893	3	3	0
1895	1	1	0
1896	5	5	0
1898	1	1	0
1899	1	1	0
1902	6	6	0
1903	7	7	0
1904	3	3	0
1906	4	4	0
1908	1	1	0
1909	1	1	0
1910	3	3	0
1911	1	1	0
1912	1	1	0
1913	3	3	0
1914	3	3	0
1915	2	2	0
1917	1	1	0
1918	2	2	0
1919	1	1	0
1920	5	5	0
1922	3	3	0
1923	3	3	0
1924	8	8	0
1925	6	6	0
1926	14	14	0
1929	5	5	0
1931	18	18	0
1934	3	3	0
1937	8	8	0
1938	5	5	0
1939	4	4	0
1940	7	6	1
1941	1	1	0
1942	0	0	0
	–	–	–
SUBTOTAL	164	162	2
Unknown	6	6	0
	–	–	–
TOTAL	170	168	2

Retirements by Years

Year Installed	Number	Year
1890	1	1937
1940	1	1940

14-IN. VALVES

Year Installed	Number Installed	In Service	Retired
1941	14	14	0
1942	0	0	0
TOTAL	14	14	0

16-IN. VALVES

Year Installed	Number Installed	In Service	Retired
1883	3	1	2
1884	7	7	0
1888	1	1	0
1889	3	3	0
1904	1	1	0
1925	1	1	0
1926	7	6	1
1927	2	2	0
1929	1	1	0
1934	3	3	0
1937	2	2	0
1940	3	3	0
1942	0	0	0
SUBTOTAL	34	31	3
Unknown	3	3	0
TOTAL	37	34	3

Retirements by Years

Year Installed	Number	Year
1883	2	1940
1926	1	1937

20-IN. VALVES

Year Installed	Number Installed	In Service	Retired
1883	1	1	0
1889	1	1	0
1893	6	6	0
1902	2	2	0
1929	13	13	0

20-IN. VALVES (contd.)

Year Installed	Number Installed	In Service	Retired
1937	4	4	0
1939	7	7	0
1940	1	1	0
1942	0	0	0
SUBTOTAL	35	35	0
Unknown	1	1	0
TOTAL	36	36	0

24-IN. VALVES

Year Installed	Number Installed	In Service	Retired
1922	2	2	0
1924	5	5	0
1942	0	0	0
TOTAL	7	7	0

30-IN. VALVES

Year Installed	Number Installed	In Service	Retired
1921	2	2	0
1923	6	6	0
1929	5	4	1
1934	4	4	0
1936	7	7	0
1937	1	1	0
1940	1	1	0
1942	0	0	0
SUBTOTAL	26	25	1
Unknown	1	1	0
TOTAL	27	26	1

Retirements by Years

Year Installed	Number	Year
1929	1	1936

HYDRANTS

4- AND 6-IN. HYDRANTS

Year Installed	Number Installed	In Service	Retired	Year Installed	Number Installed	In Service	Retired
1881	1	1	0	1915	112	106	6
1883	4	2	2	1916	107	104	3
1884	53	42	11	1917	38	36	2
1885	3	1	2	1918	29	27	2
1886	58	49	9	1920	43	41	2
1887	85	76	9	1921	69	65	4
1888	79	65	14	1922	44	42	2
1889	46	36	10	1923	98	95	3
1890	95	74	21	1924	187	179	8
1891	82	65	17	1925	171	168	3
1892	50	39	11	1926	242	234	8
1893	30	16	14	1927	29	28	1
1894	21	16	5	1928	9	9	0
1895	7	7	0	1929	36	36	0
1896	19	18	1	1930	6	5	1
1897	14	12	2	1931	163	163	0
1898	20	15	5	1932	19	16	3
1899	17	10	7	1933	21	18	3
1900	24	16	8	1934	89	83	6
1901	31	14	17	1935	27	27	0
1902	34	32	2	1936	32	32	0
1903	43	32	11	1937	148	145	3
1904	104	97	7	1938	129	129	0
1905	44	42	2	1939	149	148	1
1906	42	41	1	1940	95	94	1
1907	61	52	9	1941	81	80	1
1908	11	11	0	1942	29	29	0
1909	49	47	2				
1910	58	57	1	SUBTOTAL	3,733	3,454	279
1911	84	81	3	Unknown	328	211	117
1912	86	84	2				
1913	76	69	7	TOTAL	4,061	3,665	396
1914	100	96	4				

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year	Year Installed	Number	Year	Number	Year	Number	Year
1883	1	1934	1	1940			1885	1	1935	1	1940		
1884	1	1923	1	1924	1	1934	1886	1	1924	1	1934	1	1935
	1	1935	5	1937	1	1939		2	1937	1	1938	2	1940
	1	1940						1	1941				

4- AND 6-IN. HYDRANTS (contd.)

Year Installed	Number	Year	Number	Year	Number	Year
1887	1	1933	3	1936	1	1937
	3	1938	1	1941		
1888	2	1933	3	1937	5	1938
	1	1939	1	1940	2	1942
1889	3	1933	1	1936	2	1937
	1	1938	3	1939		
1890	1	1915	1	1920	4	1933
	1	1934	6	1937	4	1938
	1	1939	1	1940	2	1941
1891	1	1934	3	1935	1	1936
	2	1937	2	1938	5	1939
	3	1941				
1892	1	1932	2	1935	2	1936
	3	1937	2	1938	1	1939
1893	1	1931	2	1933	2	1934
	5	1935	1	1936	2	1937
	1	1939				
1894	1	1932	1	1934	1	1935
	1	1939	1	1940		
1896	1	1940				
1897	2	1941				
1898	1	1932	1	1939	2	1940
	1	1941				
1899	2	1932	1	1933	1	1939
	1	1940	2	1941		
1900	1	1932	1	1933	1	1934
	1	1935	2	1941	2	1942
1901	1	1921	1	1929	1	1931
	1	1933	1	1934	2	1935
	5	1937	1	1938	2	1939
	2	1940				
1902	1	1937	1	1940		
1903	1	1922	1	1932	1	1933
	1	1936	3	1937	1	1938
	1	1939	1	1941	1	1942
1904	1	1926	1	1930	2	1934
	2	1937	1	1939		

Year Installed	Number	Year	Number	Year	Number	Year
1905	1	1926	1	1938		
1906	1	1936				
1907	1	1922	1	1931	1	1936
	5	1937	1	1940		
1909	1	1934	1	1941		
1910	1	1940				
1911	1	1934	1	1937	1	1938
1912	1	1937	1	1938		
1913	1	1915	3	1916	1	1933
	1	1939	1	1940		
1914	2	1928	2	1941		
1915	1	1916	1	1933	1	1935
	2	1938	1	1939		
1916	1	1936	1	1937	1	1939
1917	1	1922	1	1937		
1918	1	1940	1	1942		
1920	2	1936				
1921	1	1931	2	1936	1	1937
1922	1	1931	1	1940		
1923	1	1937	2	1941		
1924	1	1926	1	1934	1	1936
	2	1937	1	1939	1	1941
	1	1942				
1925	1	1928	1	1935	1	1937
1926	3	1927	1	1936	2	1937
	1	1939	1	1942		
1927	1	1937				
1930	1	1939				
1932	3	1937				
1933	1	1937	1	1939	1	1942
1934	1	1934	1	1935	1	1939
	2	1939	1	1942		
1937	2	1937	1	1940		
1939	1	1940				
1940	1	1940				
1941	1	1941				

METERS

⅝-IN. DISC METERS

Year Installed	Number Installed	Number In Service	Number Retired
1890	7	0	7
1891	9	0	9
1892	20	10	10
1893	1	0	1
1895	27	25	2
1896	115	62	53
1897	181	149	32
1898	344	238	106
1899	488	479	9
1900	506	503	3
1901	605	603	2
1902	832	825	7
1903	803	781	22
1904	868	848	20
1905	974	972	2
1906	1,503	1,497	6
1907	1,246	1,203	43
1908	503	499	4
1909	1,099	1,096	3
1910	655	653	2
1911	611	606	5
1912	793	786	7
1913	1,033	1,019	14
1914	1,229	1,222	7
1915	1,009	1,000	9
1916	800	795	5
1917	345	341	4
1918	1,712	1,687	25
1919	1,001	1,001	0
1920	929	919	10
1921	1,279	1,263	16
1922	1,001	999	2
1923	1,415	1,413	2
1924	1,501	1,498	3
1925	1,005	1,002	3
1926	996	990	6
1928	1,002	1,000	2
1930	1,000	999	1
1931	1,000	999	1
1932	100	100	0
1933	500	500	0
1934	555	555	0
1935	1,001	1,001	0
1936	1,000	1,000	0
1937	1,000	1,000	0
1938	1,000	1,000	0
1939	1,000	999	1
1940	234	234	0
1942	656	656	0
SUBTOTAL	37,493	37,027	466
Unknown	12	11	1
TOTAL	37,505	37,038	467

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1890	1	1920	1	1922	1	1927
	2	1933	1	1934	1	1935
1891	1	1923	3	1924	1	1925
	2	1931	1	1933	1	1935
1892	1	1931	3	1932	2	1934
	1	1935	1	1936	1	1937
	1	1938				
1893	1	1930				
1895	2	1932				
1896	3	1929	4	1930	4	1931
	6	1932	8	1933	3	1934
	6	1935	11	1936	7	1937
	1	1939				
1897	1	1926	2	1929	1	1930
	2	1931	5	1932	5	1933
	4	1934	2	1935	3	1936
	2	1937	4	1938	1	1939
1898	3	1929	4	1930	7	1931
	25	1932	19	1933	13	1934
	8	1935	7	1936	3	1937
	6	1938	7	1939	3	1940
	1	1941				
1899	6	1932	1	1936	1	1939
	1	1940				
1900	3	1932				
1901	1	1932	1	1933		
1902	6	1932	1	1934		
1903	1	1930	9	1932	2	1934
	4	1935	3	1936	2	1937
	1	1941				
1904	6	1932	1	1933	2	1934
	5	1936	1	1937	2	1938
	2	1939	1	1942		
1905	1	1932	1	1939		
1906	5	1932	1	1935		
1907	4	1932	18	1934	5	1935
	3	1936	4	1937	1	1938
	1	1939	1	1940	3	1941
	3	1942				
1908	1	1933	1	1935	2	1940
1909	2	1932	1	1936		
1910	1	1929	1	1932		
1911	1	1931	4	1942		

⅝-in. Disc Meters (contd.)

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1912	1	1932	1	1933	2	1934
	1	1936	1	1940	1	1941
1913	1	1932	5	1933	4	1934
	2	1940	1	1941	1	1942
1914	1	1932	2	1933	2	1941
	2	1942				
1915	5	1933	2	1934	1	1940
	1	1942				
1916	3	1933	2	1934		
1917	1	1933	3	1934		
1918	15	1933	6	1934	1	1936
	1	1940	1	1941	1	1942
1920	5	1933	5	1934		
1921	1	1928	5	1932	1	1933
	4	1934	1	1936	3	1938
	1	1939				
1922	1	1936	1	1941		
1923	1	1924	1	1925		
1924	2	1932	1	1934		
1925	1	1928	1	1937	1	1939
1926	6	1927				
1928	1	1929	1	1940		
1930	1	1931				
1931	1	1931				
1939	1	1941				

¾-in. Disc Meters

Year Installed	Number Installed	Number In Service	Number Retired
1904	1	1	0
1908	1	1	0
1910	2	2	0
1911	1	1	0
1912	22	22	0
1914	15	15	0
1915	10	10	0
1917	5	5	0
1918	5	5	0
1919	2	2	0
1920	9	9	0
1921	40	37	3
1923	15	15	0
1924	23	23	0
1925	12	12	0
1926	20	20	0
1927	20	20	0
1928	11	11	0
1929	17	17	0
1930	23	22	1
1931	48	48	0
1942	0	0	0
Subtotal	302	298	4
Unknown	1	0	1
Total	303	298	5

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1921	2	1937	1	1938		
1930	1	1938				

1-in. Disc Meters

Year Installed	Number Installed	Number In Service	Number Retired
1900	2	2	0
1902	6	6	0
1903	3	3	0
1904	2	2	0
1905	10	10	0
1906	9	9	0
1907	5	5	0
1908	12	12	0
1909	16	16	0
1910	12	12	0
1912	45	42	3
1913	17	17	0
1914	35	35	0
1915	15	15	0
1917	34	34	0
1918	23	23	0
1919	11	11	0
1921	44	40	4
1923	25	21	4
1924	28	28	0
1925	12	12	0
1926	23	23	0
1927	10	10	0
1928	11	11	0
1929	12	12	0
1942	0	0	0
Total	422	411	11

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1912	1	1936	2	1942		
1921	1	1922	1	1935	1	1936
	1	1937				
1923	1	1935	1	1936	2	1937

1½-in. Disc Meters

Year Installed	Number Installed	In Service	Retired
1900	2	0	2
1904	5	0	5
1905	2	0	2
1906	1	1	0
1907	2	1	1
1908	1	1	0
1909	2	2	0
1910	1	1	0
1911	3	3	0
1912	*3	3	0
1913	11	11	0
1914	6	6	0
1915	6	6	0
1917	5	5	0
1918	10	10	0
1919	4	3	1
1920	5	5	0
1921	10	6	4
1924	11	11	0
1925	10	10	0
1926	16	16	0
1927	12	12	0
1929	24	24	0
1942	0	0	0
TOTAL	152	137	15

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1900	1	1919	1	1930		
1904	2	1921	2	1929	1	1932
1905	2	1929				
1907	1	1919				
1919	1	1937				
1921	2	1924	1	1941	1	1942

2-in. Disc Meters

Year Installed	Number Installed	In Service	Retired
1903	4	0	4
1904	3	0	3
1905	6	0	6
1906	2	1	1
1907	1	1	0
1909	2	2	0
1910	7	4	3
1911	2	2	0
1912	17	17	0
1913	3	3	0
1914	11	9	2
1915	4	4	0
1916	1	1	0
1917	13	13	0
1918	16	16	0
1919	8	8	0
1920	5	4	1
1921	31	26	5
1922	11	11	0
1923	20	20	0
1924	34	30	4
1925	28	28	0
1926	22	21	1
1927	9	9	0
1929	24	21	3
1930	16	15	1
1931	11	11	0
1942	0	0	0
TOTAL	311	277	34

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1903	3	1929	1	1930		
1904	1	1929	1	1931	1	1932
1905	1	1921	3	1929	1	1932
	1	1933				
1906	1	1929				
1910	1	1926	1	1930	1	1934
1914	1	1936	1	1937		
1920	1	1933				
1921	2	1933	2	1935	1	1936
1924	2	1932	2	1934		
1926	1	1936				
1929	1	1929	1	1931	1	1934
1930	1	1931				

⅝-IN. ROTARY METERS

Year Installed	Number Installed	Number In Service	Number Retired
1882	4	0	4
1884	105	2	103
1885	67	0	67
1886	138	1	137
1887	180	0	180
1888	166	2	164
1889	180	23	157
1890	176	19	157
1891	153	5	148
1892	246	10	236
1893	50	10	40
1894	58	40	18
1895	61	53	8
1896	210	31	179
1897	4	0	4
1898	25	24	1
1899	2	0	2
1900	1	0	1
1901	3	1	2
1902	1	0	1
1939	23	22	1
1942	0	0	0
SUBTOTAL	1,853	243	1,610
Unknown	43	0	43
TOTAL	1,896	243	1,653

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1882	4	1920				
1884	1	1894	6	1910	2	1911
	3	1912	3	1913	2	1914
	3	1915	4	1916	5	1917
	13	1920	11	1921	3	1922
	4	1923	8	1924	4	1925
	3	1926	2	1927	2	1928
	3	1929	2	1930	3	1931
	1	1932	5	1933	3	1934
	2	1935	1	1936	2	1937
	1	1938	1	1939		
1885	5	1910	1	1911	2	1913
	2	1915	1	1916	3	1917
	7	1919	7	1920	6	1921
	4	1922	3	1923	3	1924
	3	1925	1	1926	2	1928
	4	1929	1	1931	2	1932
	5	1933	1	1934	2	1935
	1	1936	1	1938		
1886	5	1910	1	1911	2	1912
	4	1913	3	1914	1	1915
	4	1916	6	1917	4	1919
	14	1920	16	1921	11	1922
	5	1923	7	1924	3	1925
	7	1926	4	1927	4	1928
	5	1929	3	1930	9	1931
	5	1932	4	1933	5	1934
	1	1935	1	1936	1	1937
	2	1938				
1887	10	1910	2	1911	4	1912
	2	1913	4	1914	3	1915
	5	1916	8	1917	8	1919
	15	1920	15	1921	18	1922
	4	1923	20	1924	9	1925
	8	1926	4	1927	1	1928
	4	1929	4	1930	5	1931
	7	1932	9	1933	2	1934
	3	1935	2	1936	1	1937
	2	1939	1	1941		
1888	1	1910	2	1911	2	1912
	4	1913	6	1916	7	1917
	4	1919	8	1920	13	1921
	13	1922	18	1923	8	1924
	4	1925	11	1926	3	1927
	4	1928	4	1929	4	1930
	9	1931	9	1932	8	1933
	8	1934	4	1935	1	1936
	2	1937	3	1938	1	1939
	1	1940	2	1942		
1889	1	1910	1	1913	1	1917
	1	1919	6	1920	12	1921
	6	1922	6	1923	12	1924
	4	1925	4	1926	5	1927
	8	1928	3	1929	11	1930
	1	1931	9	1932	10	1933
	12	1934	7	1935	5	1936
	5	1937	5	1938	3	1939
	7	1940	1	1941	11	1942

⅝-IN. ROTARY METERS (contd.)

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1890	2	1910	1	1914	2	1915
	2	1917	4	1919	7	1920
	4	1921	5	1922	1	1923
	14	1924	8	1925	7	1926
	2	1927	2	1928	9	1929
	6	1930	10	1931	11	1932
	14	1933	11	1934	4	1935
	7	1936	2	1937	6	1938
	5	1939	2	1940	1	1941
	8	1942				
1891	1	1911	1	1917	13	1920
	9	1921	11	1922	9	1923
	14	1924	7	1925	8	1926
	2	1928	10	1929	6	1930
	3	1931	7	1932	14	1933
	3	1934	7	1935	7	1936
	2	1937	5	1938	3	1939
	5	1940	1	1942		
1892	2	1910	1	1915	7	1917
	32	1920	27	1921	18	1922
	15	1923	24	1924	11	1925
	13	1926	9	1927	4	1928
	4	1929	9	1930	8	1931
	5	1932	16	1933	8	1934
	6	1935	7	1936	1	1937
	3	1938	3	1939	1	1940
	2	1941				

Year Installed	Number	Year	Number	Year	Number	Year
1893	1	1921	2	1922	2	1923
	4	1924	1	1925	3	1927
	2	1929	2	1930	2	1932
	9	1933	2	1934	1	1935
	3	1936	2	1937	3	1938
	1	1941				
1894	1	1920	2	1924	1	1927
	1	1929	3	1930	1	1931
	1	1932	2	1933	1	1934
	2	1936	1	1938	1	1939
	1	1942				
1895	1	1922	1	1925	1	1936
	1	1938	2	1940	2	1942
1896	5	1917	46	1920	18	1921
	11	1922	18	1923	16	1924
	7	1925	7	1926	4	1927
	2	1928	2	1929	7	1930
	6	1931	5	1932	6	1933
	2	1934	5	1935	3	1936
	2	1937	2	1938	1	1939
	1	1940	3	1941		
1897	1	1924	1	1929	2	1941
1898	1	1937				
1899	1	1923	1	1932		
1900	1	1935				
1901	2	1942				
1902	1	1939				
1939	1	1940				

¾-IN. ROTARY METERS

Year Installed	Number Installed	In Service	Retired
1883	17	0	17
1884	22	0	22
1885	15	0	15
1896	1	0	1
1942	0	0	0
SUBTOTAL	55	0	55
Unknown	13	0	13
TOTAL	68	0	68

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1883	3	1920	1	1921	1	1922
	2	1924	1	1926	1	1928
	2	1929	3	1932	2	1933
	1	1936				
1884	5	1920	1	1921	3	1922
	1	1923	1	1924	1	1927
	2	1928	2	1930	3	1932
	2	1933	1	1934		
1885	4	1920	2	1922	1	1923
	1	1924	1	1926	1	1928
	1	1929	1	1931	1	1932
	1	1933	1	1934		
1896	1	1920				

1-in. Rotary Meters

Year Installed	Number		
	Installed	In Service	Retired
1882	4	0	4
1884	14	0	14
1885	4	0	4
1887	1	0	1
1942	0	0	0
Subtotal	23	0	23
Unknown	3	0	3
Total	26	0	26

Retirements by Years						
Year Installed	Number	Year	Number	Year	Number	Year
1882	1	1920	1	1922	1	1924
	1	1930				
1884	4	1921	2	1923	2	1924
	1	1926	1	1929	1	1930
	2	1932	1	1933		
1885	1	1924	1	1926	1	1928
	1	1931				
1887	1	1931				

1½-in. Rotary Meters

Year Installed	Number		
	Installed	In Service	Retired
1883	2	0	2
1884	1	0	1
1885	2	0	2
1887	2	0	2
1892	1	0	1
1942	0	0	0
Subtotal	8	0	8
Unknown	1	0	1
Total	9	0	9

Retirements by Years				
Year Installed	Number	Year	Number	Year
1883	1	1920	1	1931
1884	1	1932		
1885	1	1925	1	1926
1887	1	1934	1	1935
1892	1	1929		

2-in. Rotary Meters

Year Installed	Number		
	Installed	In Service	Retired
1883	1	0	1
1896	1	0	1
1897	2	0	2
1898	4	0	4
1899	2	0	2
1900	1	0	1
1902	8	0	8
1903	6	0	6
1905	9	0	9
1908	1	0	1
1920	4	0	4
1942	0	0	0
Subtotal	39	0	39
Unknown	1	0	1
Total	40	0	40

Retirements by Years						
Year Installed	Number	Year	Number	Year	Number	Year
1883	1	1922				
1896	1	1926				
1897	1	1923	1	1932		
1898	3	1924	1	1929		
1899	1	1922	1	1932		
1900	1	1922				
1902	3	1921	1	1927	1	1929
	1	1930	1	1932	1	1934
1903	1	1921	1	1922	2	1923
	1	1924	1	1926		
1905	4	1920	1	1921	1	1924
	1	1925	1	1926	1	1930
1908	1	1929				
1920	2	1931	1	1932	1	1933

3-IN. ROTARY METERS

Year Installed	Number Installed	In Service	Retired
1885	3	0	3
1942	0	0	0
TOTAL	3	0	3

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1885	1	1923	2	1930		

4-IN. ROTARY METERS

Year Installed	Number Installed	In Service	Retired
1889	1	0	1
1942	0	0	0
SUBTOTAL	1	0	1
Unknown	1	0	1
TOTAL	2	0	2

Retirements by Years

Year	Number	Year
1889	1	1922

3-IN. TORRENT METERS

Year Installed	Number Installed	In Service	Retired
1906	1	0	1
1907	1	0	1
1908	2	2	0
1910	1	1	0
1942	0	0	0
TOTAL	5	3	2

Retirements by Years

Year Installed	Number	Year
1906	1	1935
1907	1	1930

4-IN. TORRENT METERS

Year Installed	Number Installed	In Service	Retired
1904	1	1	0
1907	3	2	1
1918	2	0	2
1942	0	0	0
TOTAL	6	3	3

Retirements by Years

Year Installed	Number	Year
1907	1	1930
1918	2	1926

6-IN. TORRENT METERS

Year Installed	Number Installed	In Service	Retired
1906	1	1	0
1907	1	0	1
1910	1	1	0
1918	1	0	1
1942	0	0	0
TOTAL	4	2	2

Retirements by Years

Year Installed	Number	Year
1907	1	1930
1918	1	1926

3-IN. PROPORTION METERS

Year Installed	Number Installed	In Service	Retired
1916	1	0	1
1917	2	2	0
1920	2	2	0
1923	1	1	0
1942	0	0	0
TOTAL	6	5	1

Retirements by Years

Year Installed	Number	Year
1916	1	1930

4-IN. PROPORTION METERS

Year Installed	Number Installed	In Service	Retired
1890	2	0	2
1920	1	0	1
1921	1	0	1
1922	1	0	1
1942	0	0	0
TOTAL	5	0	5

Retirements by Years

Year Installed	Number	Year
1890	2	1936
1920	1	1930
1921	1	1926
1922	1	1930

6-IN. PROPORTION METERS

Year Installed	Number Installed	In Service	Retired
1917	2	1	1
1920	2	0	2
1923	1	0	1
1942	0	0	0
TOTAL	5	1	4

Retirements by Years

Year Installed	Number	Year	Number	Year
1917	1	1930		
1920	1	1930	1	1931
1923	1	1930		

3-IN. COMPOUND METERS

Year Installed	Number Installed	In Service	Retired
1914	1	1	0
1920	1	1	0
1942	0	0	0
TOTAL	2	2	0

4-IN. COMPOUND METERS

Year Installed	Number Installed	In Service	Retired
1909	1	1	0
1926	2	2	0
1942	0	0	0
TOTAL	3	3	0

6-IN. COMPOUND METERS

Year Installed	Number Installed	In Service	Retired
1922	1	0	1
1937	2	2	0
1941	2	2	0
1942	1	1	0
TOTAL	6	5	1

Retirements by Years

Year Installed	Number	Year
1922	1	1937

Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **34:** 412 (Mar. '42) indicates volume 34, page 412, issue dated March 1942. If the publication is paged by the issue, **34:** 3: 56 (Mar. '42) indicates volume 34, number 3, page 56, issue dated March 1942. Initials following an abstract indicate reproduction, by permission, from periodicals, as follows: *B.H.—Bulletin of Hygiene (British); C.A.—Chemical Abstracts; P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (British); I.M.—Institute of Metals (British).*

SERVICES AND METERS

Water Metering at Colorado Springs. E. L. MOSLEY. Pittsburgh-Empire W. Jour. **29**: 2: 2 (Mar.-Apr. '45). Principal reasons for change from flat rate to metered basis: (1) Desire to realize best returns possible from available water resources by increasing eff. of use. (2) To secure accurate records of all facts relating to supply and consumption of water, so that highest deg. may be obtained in "beneficial use" of water diverted for domestic purposes under state law. (3) To encourage installation of improved plumbing and other appliances and their better care, without restricting necessary and reasonable use of water. (4) To encourage thrift in individual consumer and elim. discrimination as between consumers by placing burden of extravagance directly where it belongs. (5) To reduce load carried by sewage disposal plant, especially in cold weather, by stopping continuous flow of water through poorly installed plumbing fixtures to prevent freezing. (6) To give improved customer service during sprinkling season by removing all sprinkling restrictions. (7) To insure adequacy of available water supply in interests of eff. and economy and of conservation of community property in which each individual has interest, and in which he, as an integral part of community, will share. Proven that installation of meters most economical means to use to secure this end. For example, total water consumption in '43 for estd. increase in civilian pop. of 4000, plus addnl. army requirements at Camp Carson, Peterson Field and headquarters of Second Army Air Force, under full metered conditions, was only 89% of total consumption on flat rate basis in '39. *Installation Procedure:* City divided into some 51 dists. having avg. of 210 consumers each and time covered in entire program lasted from June 22, '40, to June 28, '41. Plan required property owner to pay entire cost of installing meter on his service exclusive of meter itself, which was furnished by dept., and option given consumer to have his portion of cost distributed in 12 equal installments on his monthly water bills, if cost of such installation exceeded $5.00. Consumer selected his own licensed plumber and given 30 days in each case from date of letter sent him advising that mandatory installation of meters had been ordered by city council. Plumber secured meters from city warehouse on duplicate order, plumber taking one copy and other being sent to water div. office to be checked against list prepd. there and used by inspector in checking installation to ascertain if meter properly set so as to record use of water through all outlets on premises concerned. In this way possible for office to follow up consumers who did not promptly comply with requirements, and second letter asking for immediate compliance mailed, advising that, unless meter installed in given length of time, service would be discontinued without further notice. Second letter suggested that, if consumer had special problems or conditions which prevented his complying with requirements, water div. would be glad to consult with him in effort to overcome his difficulties in satisfactory manner. Where consumers disregarded first 2 letters, third letter sent similar to 3-day shut-off notice to all util. consumers who refuse to comply with regulations or to pay for service rendered. Every effort made to secure voluntary compliance with this request before water actually turned off, and such voluntary compliance practially 100%. About 165 customers in straitened

financial circumstances took advantage of offer to allow payment in monthly installments and, while div. permitted to charge interest at rate of 0.25% per month on such deferred payments, did not actually do so. Number of consumers for one reason or another had been on metered service for years past and owned their own meters. In order properly to service these meters and to prevent discrimination, such privately-owned meters should be purchased by water div. and replaced for flat rate consumers. 732 such meters in service, of which number water div. purchased 608 and replaced 124 which were obsolete. These meters purchased on appraised basis computed at 5% depreciation per year from date of purchase to June 1, '40, which proved in most cases to be satisfactory to consumer and regular bill of sale given water div. with purchase price being paid by check. In few cases, this arrangment not satisfactory and privately-owned meter replaced with one from water div., leaving old meter to be disposed of as consumer saw fit. *Office Accounts Changed:* In case of vacant property on which water had previously been shut off at request of owner, required installation of meter on service before property again occupied and in this way transferred entire system, having 10,700 flat rate consumers, to 100% metered basis in relatively short time. After newly installed meters had been inspected and sealed, lists in office checked off and accts. transferred from flat rates to metered rates. Flat rate accts. closed out and debits or credits thereon set up on metered accts. New houses under constr. required to install water meters before completion. Meter records set up in office on card index files in numerical order as identified by city's number. Cards contain make, mfr.'s number and size, as well as name and address of consumer on whose premises meter is placed. Total cost of program to city $134,287.81, and while no accurate information available, can be safely said that consumers spent at least equivalent sum as their share of program. *Rate Computation:* One of most difficult jobs was development of metered rate schedule which would be fair and non-discriminatory to all types of consumers and at same time would bring in total operating revenue equal to that received under old flat rate schedule. Only information available on which to base calcns. was that obtained from 350 consumers served outside city limits on metered basis for many years past. Rate finally arrived at, through good luck rather than anything else, resulted in operating revenue about 5% less on metered rate than it had been prior to that time on flat rate basis. Now in third year of operation on fully-metered basis and without doubt it can be said consumers well satisfied with change and no tinkering with rate schedule found necessary. In development of rate schedule, set min. monthly bill at 75¢ which is same min. charge as that for gas and elec. consumers. For this 75¢ consumer entitled to max. of 750 cu.ft. (5625 gal.) per mo. Breakdown clerk compiles monthly statistics on number of bills falling in each bracket of rate schedule, so that at all times specific information available on revenue returns from smallest to largest consumer. In '43, 49.22% customers were min. users and they used but 56.8% of water available to them for min. charge of 75¢ per mo. Avg. revenue per 100 cu.ft. in '43 for city consumers was 8¾¢ or 11.55¢ per 1000 gal. Avg. revenue for 10,840 customers was $1.56 per mo. and avg. monthly consumption per customer was 1805 cu.ft. (13,538 gal.). Revenue on existing metered rate in '43, city only, avgd. $18.73 per tap, whereas in '39 corresponding revenue under flat rate, city only, was $19.93, representing reduction of 5.42% in avg. bill.—*Ed.*

The Pros and Cons of Domestic Supplies by Meter. J. R. ROBERTS. Surveyor (Br.) **103**: 221 (May 12, '44). Doubtless as much can be said for metering by one undertaking as can be said against it by another. Problem can be dealt with under two main headings—financial and effect on consumption of water. Tests of consumption recently carried out in Leeds of interest. Two dists. investigated, one a suburban housing estate where occupants owners of houses, and other a corporation housing estate tenanted chiefly by rehoused slum dwellers. Avg. quant. of water used in first dist. 26 gpd. (Imp.) per capita, and in latter dist. 22.5 gpd. (Imp.) per capita. Block of communal flats, tenanted by rehoused slum dwellers, also investigated. Avg. daily consumption 18.5 gal. (Imp.) per head. Method of charging for domestic supplies in Leeds based on gross value of premises. Std. charges for water by meter 1s. per 1000 gal. (Imp.) up to 400,000 gal. (Imp.) per quarter. Water rate received by corporation for house of avg. value is £2 9s. If supplies furnished by meter, corporation would receive £1 10s. Method by which this disadvantage could be

overcome would be to fix min. charge. 177,000 domestic supplies in city and each of these would require meter, so that outlay of £620,000 for meters alone would be required, apart from skilled labor and workshops for their servicing, etc. Then 70 meter readers, at least, would be required at annual wage of £225. From financial point of view nothing to be gained from change in present method of charging. Meters should act as deterrent against waste. One thing is certain, if meter is to act as deterrent against waste it must be fixed inside house where it can be read by tenant as well as meter reader. Any bursts of service pipe would be unmetered and these are likely to remain undetected for long periods. In conclusion, my opinion is that loss in income, addnl. capital outlay and increased cost of admin. would far outweigh any saving in consumption resulting from meters. *Discussion.* Wtr. & Wtr. Eng. (Br.) **47**: 352 (Aug. '44). W. GORDON LEES: Case against metering should not rest mainly on difficulties of admin. and trouble caused consumer, but rather as way of stopping waste. Metering of domestic supplies neither fair proposal nor possible solution. Metering of outside and garden supplies not only practicable but would give measure of control over that part of excessive consumption. N. B. BENNETT: In Southport, where few houses were without gardens, large quants. of water used for gardens in dry seasons. If supplies for garden hoses and sprinklers not metered consumption would rise much further. M. T. B. WHITSON: Measurement of domestic water supplies can only be justified if, by so doing, wastage of water can be reduced. Until evidence forthcoming case for metering must continue to rest on hypotheses and be of more academic than practical interest. G. E. V. BOLDRY: Water engrs. would have to advise their authorities on advantages, or otherwise, of system of metering all domestic supplies of water in order to prevent increase of consumption and would have to compare this with alternative of obtaining addnl. supplies by constructing new works. Lees has shown that these alternatives would cost roughly the same and it is generally accepted that there are unused water resources sufficient to meet greater demand than at present. Writer did not think there was any doubt what decision would be. C. F. J. LISLE: Writer unable to see benefit from metering all domestic supplies. Question whether metering would prevent waste of water not answered affirmatively. Real waste could be checked more effectively by good system of periodic inspections and at much less expense. H. R. DAVENPORT: Writer asked was it not asking too much of long-suffering rate payer that he should pay more in order that he might use less? Question would be judged mainly on its financial aspect. Difficult to make out case for metering on financial grounds for area having preponderance of working-class dwellings, where quant. of water consumed per head is low and annual rents small. E. P. BROOK: Within 4 mi. of Leeds supply to house property had been metered but now discontinued. J. A. RODWELL: Great deal can be said for principle of affording all supplies by meter. Many present will live to see day when metering comes into more universal favor. Much depends on how metering applied. By system of "open" rating careful consumer penalized by having to bear share of increased cost occasioned by his wasteful neighbor. Assumption that cost of installing meters would have to be borne over comparatively short time unjustifiable. *Author's closure:* Cost of bldg. another reservoir would be no greater than metering of domestic supplies. There would be increased water available for money spent, while in second case there would be problematical waste reduction and thousands of meters causing more worries in time of frost. With regard to watering of gardens, unless whole of premises metered, water would, in all probability, be taken from unmetered tap. Metering is not solution to problem of reducing waste. Any addnl. cost due to metering would be addnl. burden on working-class people who could least afford it. Under present circumstances not practicable to undertake individual metering of isolated blocks of property. Atkinson shows that charge for water by meter is less than cost of producing it. Made clear in paper that it would be necessary to increase charges by meter if present min. charge not applied. Statement that Leeds is supplying water at 20% below cost incorrect. Avg. cost considerably less than 1*s.* 3*d.* per 1000 gal. (Imp.).—*H. E. Babbitt.*

Some Experiences With Water Meters. HERBERT ADDISON. The Engr. (Br.) **173**: 390 (May 8, '42). Notes collected during calibrations of inferential meters of type in which water rotates helicoidal vanes, revolutions of which, expressed in units of vol., can be read from registering dials. Meters had to be put in positions far from ideal. Fore-

seen that corrections might be necessary. Set of tests carried out on improvised proportional flowmeter where small meter set in shunt circuit intended to do work of larger meter interposed normally in main pipe. Tests made at atm. temp. Tests show effect of: (1) sluice valve regulation near meter; (2) using meter with pipeline not full; and (3) setting meter in pump delivery line. Results of tests in group 1 can be dismissed for fault in mounting is specifically warned against; as soon as meter ceases to run full bore, registration will go on much as it did before, although true dischg. drops with fall in level. Serious over-registration results. In all instances (1, 2 and 3) over-registration at low rates of flow. Tests in group 3 throw light on what goes on in pump as in meter. Actual return flow appears to take place in parts of delivery pipe area. True eff. of centrifugal and similar pumps can only be assessed by making complete pressure and veloc. traverse in plane of delivery flange. Meter used in improvised proportional meter tests of vertical-spindle, vane-wheel type, of $1\frac{1}{4}$″ nominal bore. Anything that alters resistance of either circuit during use will create error, if const. factor serves to est. dischg. Clogging of meter strainer dangerous possibility. Because of variation in meter characteristics, no way of establishing value of factor except by expt. Whatever doubts and difficulties in particular emergencies, engr. would prefer to use 1″ meter for measuring flow in 12″ pipe rather than to cut pipe and put in 12″ meter.—*H. E. Babbitt.*

Report Shows Both Customer and Company Approval of Meter Reading and Billing Changes—Customer Activities Group of the A.G.A. and E.E.J. Edison Elec. Inst. Bul. **11**: 5: 129 (May '43). Report based on summary of replies to questionnaire circulated to country-wide cross-section of elec. and gas industry. Report in 3 sections covering customer acctg.-meter reading and billing changes, customer collection methods and experience and customer relations and reactions to new procedure. 67 companies reported favorable acceptance to new billing plans, 4 fair and 1 poor. On meter reading and billing changes total of 89 companies replied, 74 reported having made changes and 15 had not. 21 changed during first 6 mo. of '42, 39 during last 6 mo. and 13 during first 3 mo. of '43. Bi-monthly reading and billing, bi-monthly reading with customer-card reading in non-reading mo., bi-monthly reading with estd. or memo billing in non-reading mo., quarterly reading with customer-card reading in non-reading mo., quarterly reading with estd. or memo billing in non-reading mo. and variations in these systems adopted by respective companies reporting. Reasons given: curtailment in use of transportation equip., saving in manpower, and reduced work on billing and collection personnel and machines. Types of customers generally excluded from change were indus. and large commercial, gas accts. and house heating accts. Companies generally indicate estd. bill for information of customers. Such items as collections and disconnection of estd. or memo bills, use of outside agencies for customer convenience in payment of bills and collection of final bills commented upon. 22 companies reported changes in consumer deposit policies and 38 in collection policies. 34 reported decrease in no. of collectors. Delinquent accts. showed little change. 51 reported memo bills given same collection treatment as actual reading bills. 30 disconnected service on estd. or memo bills and 11 only with certain qualifications.—*H. J. Chapton.*

Cost of Repairing Old Meters. Anon. Can. Engr.—Wtr. & Sew. **82**: 9: 25 (Sept. '44). Data obtained by Harold Shand in study of cost of removing, repairing, testing and resetting 2968 meters ($\frac{5}{8}$″) in Winnipeg in '41 presented. Costs include labor, material and supervision, 60% of storekeeper's time, $11\frac{1}{3}$% of office admin. expense, 44% of capital and maint. charges on bldg. in which meter shop located. Majority of Winnipeg meters in service 20 yr. or more, with practically no maint. Avg. cost $9.81. On basis of schedule followed during '35–'41, all $\frac{5}{8}$″ meters would be overhauled every 10.6 yr. and cost would be $0.924 per yr. Thos. Hodkinson states that avg. cost of removing, repairing, testing and resetting 4873 meters of similar size in London, Ont., in '43, was $1.75. All meters overhauled every 5 yr. Revenue of dept. increased greatly by maintg. meters at highest eff.—*R. E. Thompson.*

Atlanta "Retreads" Service Pipe. Paul Weir. Southern Power & Ind. **60**: 3: 46 ('42). Badly corroded 6″ c-i. pipe with internal tubercles restricting flow cleaned internally and externally. Then coated internally with Portland cement mixt. on spinning machine, and finally with asphalt emulsion. Exterior of pipe coated with as

phaltic paint and ends of pipe capped to facilitate curing. About 50 lb. cement mortar used in lining each 12′ section of 6″ pipe; this insures lining of approx. $\frac{1}{8}$″ thickness. Portland cement of low soly. selected by anal. 90 lb. of sand used with each sack of cement. Special study made of most suitable cement consistency. Tap holes in pipe closed with brass plugs before lining. Cost per ft. of lining estd. as $0.126.—*C.A.*

Water Pipe Services in Buildings. ANON. Wtr. & Wtr. Eng. (Br.) **46**: 106 (Mar. '43). Modification of scheme of identification laid down in '35 edition of British Standard 617 (Identification of Pipes, Conduits, Ducts and Cables in Buildings) suggests identification letters painted on pipes in color contrasting with basic color on pipe itself, e.g., "Cold Water-Town Main" by WCT.—*H. E. Babbitt.*

FOREIGN WATER SUPPLIES—GENERAL

Sources of Water Supply to the London Area. H. A. P. HETHERINGTON. Wtr. & Wtr. Eng. (Br.) **47**: 335 (Aug. '44) (*Abstracted*, Jour. A.W.W.A. **37**: 121 ('44)). *Discussion. Ibid.* **47**: 454 (Oct. '44). P. G. H. BOSWELL: Although London basin forms well-defined geol. unit, hydro-geol. conditions in different parts vary to considerable extent. It may be misleading, therefore, to make use of figures of avg. rainfall, runoff, evapn., etc., for area as whole. Author says that evapn. "may and probably does amt. to as much as between 60 and 70% of total rainfall." If this figure applied to calcns. for Lee catchment area above Feilde's weir, between 13.6 and 3.6% of rainfall is left to satisfy ground water increment. But more than 44 mgd. (Imp.) being pumped from upper Lee catchment area, besides which excess underground water still flows to deeper levels under London. Writer believes assumption of from 60 to 70% for evapn. unwarranted. In 1893 R. E. Middleton investigated flow of headwaters of Lee, Stort and Colne. He demonstrated how little reliance could be placed on impressions of local inhabitants. Boswell suggests author, at some future date, summarize evidence of diminution of flow and indicate to what extent it was due to regional fall of water table or to local failure of springs due to pumping in vicinity. Rise of standing water levels under London, which has resulted from diminution of pumping in immediate neighborhood, shows that considerable vol. of water still percolating under Metropolis. In setting up National Water Com., regional advisory coms. will be necessary. Govt. considers that there is prima facie case for coms. for Greater London Area. F. H. EDMUNDS: As schemes for extraction of large vols. of underground water increase, maint. of economic balance between underground extraction and surface flow becomes necessary. Several indications of apparent maladjustment of economic balance visible. Good instances furnished by watercress beds on chalk fed by springs or artesian wells relatively near London. Demands on underground water have reduced local water table to affect seriously watercress interests. In this case economic problem has solved itself by extinction of watercress beds but without compensation to watercress industry. Effect of abstraction of underground water on stream often mitigated by return of sewage effluent. N. G. ELLIOT: London basin being overpumped. Proper water supply to London vital. Water supply communal enterprise and its value to each individual does not rest entirely on his own consumption. Domestic water supply should be treated as essential public health requirement. "Water charges" should be changed to "water rates" to be levied on property holders whether they use water or not. DAVID LLOYD: Rapid drop in water level in chalk under London in '20–'40 local problem related to permeability of strata rather than general depletion of underground water in Greater Thames Basin. In general no reservation need be applied to author's statement that "ground is full of water to within limits prescribed by existing discharge points and the nature of the geol. formation." Rainfall has been given form of: direct surface runoff + soil water evapn. loss + ground water evapn. loss + ground water effluent. If author expresses equality as $R = S + I + E$, without qualifying adjectives, there would be left an increment accumulating until floods of Noah would be permanent. J. P. LEGRAND: Water levels in various boreholes, taken before and during war period, show rapid recovery of underground water table in central London due to reduction in pumping

during war. In one or two cases found necessary to raise air-lift pumps because of abnormal air pressure caused by rise in water level. *Ibid.* **47**: 536 (Dec. '44). F. K. SINCLAIR: Although in general pumping from chalk must be cause of decrease in yield of Chadwell Spring, author has not proved satisfactorily that pumping from Metropolitan Water Board's wells in vicinity has not also been responsible. Valuable replenishment of water in chalk on northwestern side of London Basin is infiltration of flood water through superincumbent gravel beds in valley of Colne for distance of about 9 mi. Thames Conservancy Board instituted cleaning of channel of Colne with result that flooding decreased substantially. Policy appears ill-advised. Large quants. of water discharged to sea which would otherwise be diverted into chalk and serve useful purpose. Foresee difficulties if author's proposal to limit abstraction from chalk under London were put into practice. Limitation of abstraction would force firms concerned to take supply from Metropolitan Water Board and to incur substantially greater expenditure. Problem would be solved automatically if supplies afforded by meter. *Ibid.* **48**: 80 (Feb. '45). *Author's Reply:* Boswell correct in pointing out that catchments of more important tributary streams can be dealt with as units, but, ultimately, they must be correlated to whole geol. unit. Recent calcn. in Thames catchment area has shown evapn. to be approx. 65% of rainfall. Suggestion that "water charges" should be changed to "water rates" would be excellent solution of present anomalous system of assessment. Recent est. appears to show that water that percolates into ground in Greater Thames Basin and does not reappear as runoff, is about 3.5%, while about 14% percolates into ground to reappear and form part of runoff.—*H. E. Babbitt.*

Postwar Sanitary Engineering Problems. Inst. of San. Engrs. (Br.) ('44) 20 pp. Prevailing san. conditions in towns and in rural areas in Great Britain reviewed. Recommended that houses built in future shall be provided with piped supply of pure water, indoor sanitation and facilities for bathing, and efficient drainage system; and that existing houses shall be modified within limited period to comply with stds. for new houses. Insistence on right to discharge water from roofs and yards to public sewers could prevent successful operation of new sewerage system. Planned drainage should form basis of both rural and urban development. Building should be forbidden on land which cannot be drained economically or which is liable to be flooded. To insure most efficient use of sources of water supply, conservation of water necessary. Information should be collected and published on flow of rivers and streams, on wells and boreholes, on amts. of ground water available and possible effect of abstraction of water on resources of neighboring areas. Establishment of river boards, as suggested in Third Rpt. of Central Advisory Water Com. recommended. Boards should not initiate sewerage or water supply schemes but should be notified of proposed schemes and should possess powers to enable them to insure that sewage disposal and sewerage schemes adequate. Regional sewage authorities and regional water authorities should be created, each water authority and each sewage authority to exercise control over 1 watershed. Research should be done on methods of prepg. sewage sludge for use as fertilizer. Critical reviews of literature on eng. and allied subjects should be issued periodically. —*C.A.*

Water Supply—Economic and Social Influences. DELWYN G. DAVIES. Surveyor (Br.) **103**: 247 (May 26, '44); (*Abstracted,* Jour. A.W.W.A. **36**: 1011 ('44)); *Discussion.* Wtr. & Wtr. Eng. (Br.) **47**: 350 (Aug. '44); (*Abstracted,* Jour. A.W.W.A. **37**: 119 ('45)); *Discussion.* Wtr. & Wtr. Eng. (Br.) **47**: 535 ('44). S. G. BARRETT: Rate of water consumption to some extent dependent on opportunities to draw water from supply system but amt. of water used in home varies with situation, plumbing system and way of life of individual. No common std. of personal habits and individual use of water differs on that acct. *Ibid.* **48**: 77 (Feb. '45). Agreed that consumption influenced by connections per head and stds. of living. Chart showing consumption rates in dispute is composite picture of approx. avgs. rather than one of math. exactitudes. Bachelors of 30 plus use more water than their grass widower equivalents living in similar circumstances. Temp. of hot water has some influence. Tepid water is let to waste in anticipation that it may eventually become hot. Figure of 40 to 50 gpd. (Imp.) per head of dairy cattle based on modern dairy farm practice. Business of water engr. not merely to supply citizens with water, but to consider also what education is

necessary to promote best use of water. Porteous takes author to task for inferring certain relationships in his anal. of water consumption. Better an approx. solution by logical simplification than one by guessification. Atm. poln. diagram, showing relation between intensity of poln. and water demand, can only be accepted as trend. Opinion that London water is safest based on objective study and not on diplomatic credulity. Majority of smaller water authorities do provide remarkably pure water.—*H. E. Babbitt.*

The New Chertsey Pumping Station of the Working Water and Gas Company. J. DALRYMPLE. Wtr. & Wtr. Eng. (Br.) **48**: 27 (Jan. '45). In '39 pop. supplied within statutory area of 63 sq.mi. about 66,000. Undertaking has 3 sources of supply. Main source at Chertsey provides water from shallow well in gravel beds. New pumping station bldg. mainly of brick constr., internal length of 65′ and width of 24′ extending to 33′ behind switchboard. Aim throughout constr. of mchy. foundation was to elim. transmission of vibration by isolating mchy. foundation block from rest of bldg. Feature of internal arrangement is transverse group of rooms consisting of lavatory, office and chlorinating equip. Diesel engine is Allen 6-cylinder, vertical, airless injection type, working on 4-stroke cycle, having cylinders 325 mm. bore and stroke 370 mm. Rating of engine at max. duty is 426 bhp. 50-kw. Allen generator provides current for lighting and power for domestic purposes, auxiliary mchy. and low-lift pumping plant. Water drawn from well with vertical single-stage Allen "Conqueror," double-suction centrifugal pump, driven by Allen 53-hp. motor. Unit capable of delivering 3.5 mgd. (Imp.) against max. head of 50′. After filtration water flows by gravity to high-lift plant by which it is pumped to dist. —*H. E. Babbitt.*

Rural Water Supplies. S. R. RAFFETY. Wtr. & Wtr. Eng. (Br.) **48**: 138 (Mar. '45). Difficulties with rural water supplies almost entirely financial and administrative. If those could be overcome eng. and tech. problems seldom exceptional. In national interest that schemes should have widest practicable use and accordingly reasonable that dists. lying on or near aqueducts should participate in schemes on equitable terms. Whatever other works are necessary expenditure on mains should seldom be less than 70% of whole scheme. Best procedure is laying of relatively small mains over greatest possible area rather than system of trunk mains with service main radiating from them. Leakages difficult to trace and in some rural undertakings more than half of water which leaves source never reaches consumer. Almost as much to be said for helping potential consumer in initial cost of service connection as for rate payer in respect to scheme generally. Where water requires treatment almost overwhelming case for regional scheme. Neglect of rain water storage as form of water supply due to crude way in which rain water usually collected and stored. Preferable to use water from roofs for purposes which do not require high std. of purity and to construct artificial collecting areas of corrugated iron or asbestos-cement sheeting for domestic purposes.—*H. E. Babbitt.*

Victorian Water Law. ANON. Wtr. & Wtr. Eng. (Br.) **48**: 52 (Feb. '45). (From Extract from Evidence presented to Victorian Parliament Public Works Com. by Chairman of State Rivers and Water Supply Com., Lewis R. East, Jan. 12, '43). Common law of England conferred riparian rights only on riparian owners, and no such rights could extend to those whose lands did not abut on streams or rivers. Probably first step toward conservation of water resources for public use was taken when provision was made in Land Act, 1869, for permanent reservation of Crown lands for public purpose. In 1881 Minister of Lands recommended that large number of lakes, rivers, inlets and water courses be permanently reserved. In 1884 Royal Com. on Water Supply appointed. As result of recommendations of commission, Parliament passed comprehensive Irrigation Act, which went long way towards nationalizing water resources of Colony. Summarizing law, and referring to latest consolidation, i.e., Water Act, 1928, No. 3801, position now is that right to use, flow and control of natural streams vested in Crown. Owner of land may nevertheless drain or make dam or tank on his land; but in such case analogy of common-law principle of "reasonable user" followed in proviso that flow of any river, etc., must not thereby be sensibly diminished.—*H. E. Babbitt.*

Water Supply Before and During the Nineteenth Century. F. W. ROBINS. Wtr. & Wtr. Eng. (Br.) **47**: 459 (Oct. '44). Al-

though water wheel as motive power for water works survived into 19th century, its death knell sounded during 18th when Newcomen steam engine adopted. First installation was at York bldgs., London, in 1720. Early pump history more closely connected with mine working than with water supply. In 1795 James Watt erected steam engine for Hull Water Works. In 1803 Watt steam engine installed at Marly Water Works. In 1838, Cornish engine, std. for mine purposes, given trial at London Water Works. Great aqueducts of old type built at Rio de Janeiro in 1750, Marseilles in 1830, and New York 1837–42. In 1829 James Simpson introduced sand filtration. Cast iron had been used for mains at Versailles in latter half of 17th century. West Middlesex Water Co. exptd. with stone pipes at beginning of 19th century, and substituted iron for wood pipes in 1808. Little heard of wood pipes after opening of 19th century. Up to 18th century, with rare exceptions, such as New River Co., water supply provided at instigation and cost of church or of burgesses. In 1819 Edinburgh handed over its water supply to company in return for £30,000. Early water acts left matter of charges to mutual arrangement. Growing needs and competition for sources caused authorities to look further afield for their water supplies. In 1859 Glasgow annexed waters of Loch Katrine for its supply, brought water through 26 mi. of tunnel. By middle of 19th century almost every house in London had cistern filled at stated times. Paris still relied to considerable extent on water carriers. In Britain, so far as larger towns concerned, pendulum has swung back to public ownership. Apart from great gravitation schemes, feature of 19th century was development of artesian well. Well took its name from Artois, France, where it was supposed to have originated in 1126. Olympiodorus, 5th century A.D., refers to well depths of 600′ or more. At Grenelle, near Paris, artesian well taken down 1800′. At Putnam Heights, Conn., one reached 6000′. Hydr. ram, invented by Montgolfer, patented in 1797. In 1868 John Blake patented ram capable of raising 100,000 gpd. (Imp.) and rams now made capable of raising 500,000 gpd. (Imp.).—*H. E. Babbitt.*

Medieval Water Supplies. F. W. ROBINS. Wtr. & Wtr. Eng. (Br.) **47**: 563 (Dec. '44). Earliest example of work of monasteries in England in water eng. is water supply of Benedictine Priory of Christ Church, Canterbury. Work carried out in 1160. Original plans can still be seen. At later dates many larger monastic establishments and some smaller had supplies brought in from outside. Cistercian order paid great attention to provision of good water in their houses. At Sudbury, Suffolk, Dominican friars obtained from Richard II right to certain spring outside town and brought water by subterranean aqueduct. At Southampton there is example of supply being brought in for conventual house but made available to townspeople as well. In 14th century there was dispute about water between Benedictine Abbey of St. Peter at Gloucester and Friars Manor. Black Prince, called in as arbitrator, made award that Abbey should grant friars right to third of water. Of ecclesiastical, though not mainly monastic origin, is medieval water supply of Exeter, which provides well-preserved system of Middle Ages. Extensive system of tunnels under city carried water from St. Sidwell's well to cathedral and city. Henry III had water laid to Westminster Hall by means of hollow pipe "not thicker than a quill." Hull citizens attempted to augment supply by taking water from other sources in vicinity, resulting in acrimonious disputes with villagers. Opposition was somewhat drastically overcome by hanging some of objectors.—*H. E. Babbitt.*

The London Water Supply in the Middle of the Nineteenth Century. A Contribution to the History of Water Biology. H. BERGER. Kleine Mitteilungen (Ger.) **18**: 200 ('42). Donné assumed to be first to call attention to large numbers of "animascules infusoirs" present in Rhone R. water when plans afoot to use river as source of drinking water for city of Lyon in 1840. 10 yr. later, A. H. Hassel published microscopic examn. of water supplied to London and suburban dists. Listing of organisms and reproduction of original microphotos. 3 yr. later, F. Cohn published similar study.—*Willem Rudolfs.*

Water Supply of Algiers. MICHEL RAINEAU. Wtr. & Wtr. Eng. (Br.) **47**: 463 (Oct. '44). Water obtained from 36 wells, principal of which, at l'Harrach and Baraki, yield 14 mgd. (Imp.). Sufficient for needs except on some summer days when demand may reach 16 mil.gal. (Imp.). l'Harrach and Baraki water works, 9 mi. from Algiers, equipped with 29 elec.-driven pumps and storage reservoirs

Labs. for water examn. at these stations and elsewhere. Pop. now about 500,000, exclusive of soldiers. Supply position complicated by shut-downs of pumping plant for repairs, which take place nearly every day. Storage reservoirs at l'Harrach are covered masonry and concrete cisterns, each of which has capac. of 2.2 mil.gal. (Imp.). Water from l'Harrach and Baraki pumping stations delivered to service reservoir (capac. 3.3 mil.gal. (Imp.)) in Mustapha Hills, 5 mi. from Algiers. From here, delivered to smaller service reservoirs in heights above town. In city of Algiers water distributed to tanks on flat tops of houses. Municipality sells water to house-owners who retail it to tenants. Amt. allowed usually min. of 11 gpd. (Imp.) per inhabited room. Revenue from water sales is about £140,000 per yr. In Casbah, native quarter, 32 public fountains erected in addn. to fountains built long ago by pious Moslems. Other large towns of Algeria obtain water in much same way except Bone, where two Roman cisterns, dating back some 2000 yr., are in use. Many Roman water works constructed in Algeria. Large new water works project being planned for Algiers in which water will be brought from distant sources by aqueducts and pipes. —*H. E. Babbitt.*

Bulgarian Water Supply. D. VASIL'EV. Tech. Gemeindeblatt. (Ger.) 99 ('42); Wasser u. Abwasser (Ger.) **40**: 146 ('42). Good water supplies available to 51% of inhabitants. Of cities and villages with modern water supplies, only 17 use ground water and 3 use river water; rest use spring water. Filtration and chlorination plants required at but few localities.—*C.A.*

Water Purification in China. ANON. U.S. Army Med. Dept. Bul. *No. 85:* 37 (Feb. '45). Water supplies in China notoriously bad with regard to almost all factors by which water supplies judged. Water boiled before use, but because of universal employment of coolies for handling water, recontamn. usually occurs before water used. No. of new diatomaceous earth filters, developed by corps of engrs., Ft. Belvoir Lab., in co-operation with San. Eng. Div. of Preventive Medicine Service, Surgeon General's Office, flown to China and installed by Capt. C. W. Bovee, Sn.C., at no. of A.T.C. stations. Reports on operation of these units indicate that excellent results being obtained. Water normally being produced with turbidity less than 1.0; amoeba cysts removed; after filtration, water chlorinated. In most places, simple tank and piping system installed so that water delivered under pressure to mess halls; provision made for filling canteens and Lyster bags. In most of these installations, water coagulated and settled before filtering, as this greatly lengthens filter runs and saves diatomaceous earth. Both aluminum sulfate and lime (or soda ash) available in China. Std. portable sand filter can produce good water with coagulation and settling, but unfortunately these procedures seldom employed.—*Ed.*

Finland's Water Supply. J. L. W. LILLJA. Gesundh.-Ing. (Ger.) **65**: 272 ('42); Wasser u. Abwasser (Ger.) **40**: 165 ('42). Ground water relatively scarce, so most communities supplied from lakes or rivers. Surface water usually treated with $Al_2(SO_4)_3$ and lime and filtered to remove humus color. Magno used in some installations to remove iron and free CO_2.—*C.A.*

Water Supply in Honolulu. ANNABEL DAMON. Wtr. & Wtr. Eng. (Br.) **48**: 86 (Feb. '45). Increased pop. in Honolulu, coupled with prolonged drought, has brought about acute water supply problem. Consuming 35 mgd.—a dangerous encroachment on reserves. Honolulu today living in year 1965 so far as water consumption is concerned. One of first moves has been constr. of underground pumping station at Halawa and laying of 4 mi. of 42" pipe to center of city. Rain water from hills filtering into artesian supply and sea water act in balance, one holding back other. Any dangerous lowering of artesian heads would permit salt water to flow underground, surrounding and destroying wells. Halawa project, begun in '41 and expected to be completed in Nov. '44, makes available addnl. 15 to 20 mgd.—*H. E. Babbitt.*

Drinking Water in the Towns of Latvia. Gas-u. Wasser (Ger.) **86**: 215 ('43). Paper by Kursitis on water supplies of Latvia published in Dtsche Ztg im Ostland. Water supply of Riga ground water of good qual. obtained from wooded dist. Mitau obtains good but not quite sufficient supply from deep wells. At Libau water obtained from individual artesian wells in dolomite formation; yield insufficient. Subsoil under town has only slight purifying effect on water

percolating through it. In Windau yield from wells also insufficient; only source of adequate supply of good qual. about 10 km. from town. Dünaberg uses river water which is filtered; qual. and quant. of this supply not satisfactory and new source of supply being sought. New supply could be obtained from ground water in sandy soil or from artesian water in Red Sandstone. Supplies of smaller towns frequently insufficient.—*W.P.R.*

The Water Supply of Mogliano. L. VOLLO. Ann. Lavori Pub. (It.) 587 (July '40); Tech. Gemeindeblatt (Ger.) **44**: 78 ('41). Water supply system of Mogliano put into operation in Jan. '35. Water obtained from 2 wells, one 245 m. deep and other 195 m. deep, drawing water from 2 separate strata. After 4 mo. of operation, thin skin observed on surface of water in reservoirs and ppt. seen at bottom. At same time consumers complained of turbidity and brown color. Prelim. investigation attributed turbidity to sections of distr. system rarely used and in which water stagnated. Thorough flushing of system brought some improvement. Bact. and chem. investigations showed that water rich in iron and contained algae and segmented worms similar to those found in bogs; though not pathogenic, undesirable. Also found that on water from shallower well after exposure to air for 20 days, film formed which contained iron bacteria and other micro-organisms. In Sept. '39 third well 200 m. deep constructed near 2 original wells, which were then abandoned. Concluded that in this dist. 2 separate water-bearing strata exist, water from one of which affected in qual. by presence of peat deposits.—*W.P.R.*

The Water Supply of Auckland, New Zealand. ANON. Wtr. & Wtr. Eng. (Br.) **47**: 508 (Nov. '44). Extracts from annual rpt. for year ending Mar. 31, '44, by A. D. Mead, Munic. Water Engr. Avg. daily water consumption 14.177 mil.gal. (Imp.), equal to 78.33 gpd. (Imp.) per capita. Succession of 7 abnormally dry months, coupled with increased military and indus. demands, necessitated restrictions of consumption and use of auxiliary sources. Pumping installations made on Lower Nihotupu and Lower Huia streams, intercepting much larger areas than possible with previous emergency arrangement. Extension of headworks commencing along Lower Nihotupu adopted in Apr. '43. Prelim. work on site of dam and its design being carried out. Supply and installation of addnl. filter equip. being carried out by Candy Filters, Inc. Progress with schedule of works delayed by war.—*H. E. Babbitt.*

Municipal Water Supply in Rumania. L. STANISAVLIEVICI. Gas-u. Wasser. (Ger.) **85**: 50 ('42). Water supply systems of Rumania described. Data given refer to yr. '39. Of total area of country 88.6% drains to Danube. All towns with pops. of more than 20,000 possess central water supplies but ¾ of towns with less than 20,000 inhabitants possess no central water supply. Of 70 towns with central water supply systems, 13 use surface water or mixt. of surface and ground water, 11 use springs, and 46 use ground water. All waters have pH value greater than 7.0 except 3 ground waters of which pH values are 6.6 to 6.9. Total hardness in 30 of 35 waters tested less than 20° (Ger.). Permanent hardness low in all waters. About ⅓ of waters tested contain alkali salts in amts. ranging from 7 to 302 mg. (as Na_2CO_3) per l. Majority of these alk. waters ground water from Quaternary strata. Ground water from older rocks less alk. Demand for water in Bucharest about 200 l. per head per day. In other towns demand varies from 15 to 165 l. per head per day. Water works of Bucharest and of Timisoara, Galaţi and Târgovişte briefly described.—*W.P.R.*

Water Supply for Hannover in Middle Ages. H. BERGER. Kleine Mitteilungen (Ger.) **18**: 177 ('42). Water carriers delivered water to homes. Obtained from Leine R. where wooden water wheel poured water in vats. Wheel mentioned in 1352; rights leased; cost 8 pfs. per vat, equal to one day's labor wages. In 1535 water works built consisting of wooden structure with 12 pumps, which in 12 hr. delivered about 300 cu.m. water to wooden pipeline distr. system. Wooden pipes small with low pressure. Brewers had first call on water. In 1794 wooden pipes interconnected; during freezing weather connections covered with manure. Water rents paid once a year and celebrated. Celebration became so elaborated that city ordinance required that not more than 4 different dishes could be eaten; std. fine was 1 ton beer. Wooden pumps kept in operation from 1534 to 1848 (313 yr.) without changes. In 1848 new pumps constructed. In 1862–64 second water works built; first modern water works

built 1878, extended in 1899, '11 and '30. Original water works, still in operation in '42, had no connection with new works.—*Willem Rudolfs.*

The Hydrogeology of the Region Supplying Water to the Budapest Water Works. D. MOLNÁR. Water. *A Yearbook for Water Chemistry and the Technic of Water Treatment.* **XV** ('41–'42). Verein Deutscher Chemiker. Verlag Chemie, G.m.b.H. (Ger.) ('42) 368 pp. Water works at Budapest, with exception of 2 oldest works, at southern end of island of Szentendre and on bank of Danube on Pest side. Water obtained on island from Pleistocene stratum and conducted through tunnels and siphon laid in Miocene strata to pumping stations on banks of river. Series of wells on Pest bank of river. Test borings have shown that water from sandy loam of Miocene strata and that from Pleistocene stratum very similar, except that former contains considerable amts. of sodium and little calcium and magnesium, whereas latter contains little sodium and considerable amts. of calcium and magnesium. Process of ion exchange evidently occurred. Water trickling through wall of siphon at Buda side of river found to contain 1400 mg. of sulfate per l. Sulfate found to originate from surface water entering crevices in limestone and from oxidation and soln. of pyrites in rocks fissured by constr. of siphon. High contents of sulfate occur only intermittently and water not seriously corrosive to concrete. Silting up of Danube at Budapest and its effect on compn. of water and difference in compn. of 2 types of ground water which reach wells discussed. These 2 ground waters are stream which flows under Danube in same direction and ground water which flows in opposite direction near banks. Budapest water works supply 400,000 cu.m. of water daily, from 20,000 cu.m. of which iron and manganese removed by super-chlorination process. Chem. compn. of water supply shown in table. Avg. bact. count 11/ml. *Esch. coli* absent from 100 ml. in 98.64% of samples tested.—*W.P.R.*

The Development of the Water Supply of the Former Town of Altona, From a Hygienic Point of View. E. GRILL. Arch. Hyg. u. Bakt. (Ger.) **129**: 219 ('43); Gas-u. Wasser (Ger.) **86**: 216 ('43). On Apr. 1, '38, Altona incorporated in Hamburg and water works taken over by Hamburger Wasserwerke G.m.b.H. Before 1858 Altona obtained water from individual wells; from 1859 to '29 treated surface water used, and since '29 ground water used. At time of great cholera epidemic in Hamburg, Altona using surface water, and protective action of slow sand filtration clearly shown. Later, because of increasing poln. of River Elbe, chem. treatment of raw water introduced; water filtered through rapid sand filters and chlorinated. Activated carbon used successfully for removal of tastes and odors from raw water. Elimn. of surface water from supply began in '29 and practically complete by '36. Ground water aerated to remove iron; bact. and chem. qual. satisfactory. Treated water never contains more than 1 bacterium per cm. and always free from *Esch. coli.*—*W.P.R.*

Observations on a Small Water Supply Plant Situated Within the Area From Which a Supply of Ground Water Is Taken for a Large Town. W. AUSTEN. Gas-u. Wasser. (Ger.) **83**: 650 ('40). To obtain supply of water for house in dist. from which supply for Breslau obtained, well, about 4 m. deep, constructed about 200 m. from munic. wells. Prelim. tests had shown that ground water pumped in neighborhood of house contained small amts. of manganese and moderate amts. of dissolved iron and free carbon dioxide; its carbonate hardness not great and was aggressive. Plant built to remove CO_2, iron and manganese. In course of time amt. of free CO_2 in water increased considerably. Passage through Magno filter produced potable water although not all CO_2 removed in filter. Residual CO_2 could be removed mechanically. 2 samples of water taken at interval of 4 days from pipe from Magno filter showed that amts. of CO_2 and manganese could increase and carbonate hardness could decrease appreciably in short period of time. House well deepened and abundant supply found in clay stratum. Except for very high content of iron this water similar to that obtained from shallow well after considerable amts. of water drawn off. Compn., however, very different from that of water in munic. wells. Another test boring to depth of 6 m. yielded water similar to that in house well but contg. little iron, and new well constructed at this place to serve house. Changes in compn. of water attributed to fact that at first water mixt. of ground water and surface water which had filtered through soil, whereas later, because of lack of rain, no surface water reached ground water and level of latter

became lower, so that water in well obtained only from lower strata. Because consumption of water in house small, this change at first not noticed. New treatment plant built in house; water first aerated to oxidize dissolved iron and then filtered through gravel and Magnomasse to remove CO_2, iron and manganese.—*W.P.R.*

Water Supply in the Soviet Union. M. PORFIRYEV. Wtr. & Wtr. Eng. (Br.) **47**: 551 (Dec. '44). Aggregate length of water mains in Soviet Union exceeds 18,000 mi., of which over 30% laid in past decade. Existing stds. of daily consumption of water for domestic purposes per person are: (a) In built-up areas, where houses equipped with water supply, drainage and baths, from 20 to 26 gal. (Imp.); 33 to 44 gal. (Imp.) where hot water supplied centrally from munic. hot water mains. (b) In dists. where houses equipped with water supply and drainage but no baths, from 13 to 17 gal. (Imp.). (c) In dists. where water not laid in houses, but obtained from street pumps, from 7 to 11 gal. (Imp.). In Moscow consumption reaches 55 gal. (Imp.). Plan of further development will allow for 192 gal. (Imp.). Sources of supply invariably selected with aid and advice of san. authorities. As rule, 2 zones marked out for protection of sources: (a) stringent zones, where all bldg., picnics, boating, fishing, etc., forbidden; (b) zone of limitation, where stringent san. supervision exercised over indus. enterprises likely to contam. water. All water drawn from open sources purified in settling reservoirs, coagulated, filtered and disinfected. Water supplied for household purposes must fulfill stds. set up for drinking water. Rapid growth of industry has created increased demand for water. War has necessitated modifications in character of indus. and urban bldg., and of water supply. '41 witnessed grand migration of industry to east. Water supply systems had to be installed under severe conditions of Siberian winter. Methods devised to lay and test water pipes in fierce frosts. When forced to retreat, Germans vented spite in wanton destruction. Water works one of chief objects of reprisal. Mchy. either blown up or carried away. This was fate of works at Stalingrad, Kharkov, Voronezh, Rostov, Sevastopol, Kiev, Smolensk, Vyazma and many others. Damage to water mains usually localized. Principal methods of rehabilitation set forth in special instructions and manuals. While temporary supply being arranged, permanent installations, as have survived, are tested and capital repairs proceeded with. "Rehabilitation" does not necessarily imply restoring all water works as they were before. Course of military events dictates need for energetic postwar water works development. Main features of this are: (a) mass constr. work and necessity for water in inhabitated places where hitherto no water mains had existed; (b) necessity of finding economical way of jointly serving urban pop. and industry; (c) all-round utilization of water resources, utilization of reservoirs to prevent inundation, etc.; (d) broad development of regional water supply systems embracing towns, and indus. enterprises where local water resources inadequate. Many plants, which before war mfd. pipes, pumps, etc., have been destroyed. Research institutes and business organizations drawing up lists and specifications of materials and equip. needed for postwar development.—*H. E. Babbitt.*

Dnieproges Will Live Again. ARKADY EVENTOV. Wtr. & Wtr. Eng. (Br.) **48**: 84 (Feb. '45). When Dnieproges plant was functioning waters of Dnieper passed through crest of dam above tunnel. Now being kept as low as possible to enable greatest amt. of work to be done on dry land. Necessary to clear away more than 125,000 cu.yd. of wrecked reinforced concrete, 10,000 tons of ruined steel sections and over 18,000 tons of equip. blown up by Germans. Then necessary to lay 175,000 tons of new concrete, prepare and replace about 8000 tons of metal work, and receive from factory and assemble 18,000 tons of equip. Most of housing accommodations for workers rebuilt. Foundry, fitting shop and mech. depts. producing. Constr. of concrete factory nearing completion and mech. plant being rehabilitated. State has allocated about $20,000,000 this year for restoration work alone.—*H. E. Babbitt.*